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Coal: DRDF (Densified Refuse Derived Fuel) Demonstration Test in an Industrial Spreader Stoker Boiler. Use of Coal: DRDF Blends in Stoker-Fired Boilers, Appendices A, B, C & D. V, II

Systems Technology Corp.
Xenia, OH

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

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COAL:dRDF DEMONSTRATION TEST
IN AN INDUSTRIAL SPREADER STOKER BOILER

Use of Coal:dRDF Blends in Stoker-Fired Boilers

Appendices A, B, C, and D

Volume II

by

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EPA Contract Number 68-03-2426

Project Officer

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16. ABSTRACT

This study program has the overall objective of evaluating boiler performance and environmental feasibility when combusting densified forms of refuse derived fuels (dRDF) blended with coal and fired in a modern industrial spreader stoker-fired boiler.

The results reported herein represent the second phase of a two-phase evaluation program. Phase 1 was conducted in an institutional spreader stoker heating boiler. During Phase 1 285 tons of dRDF were combusted. The results of that test are reported in EPA Report No. 600/2-80-095. Phase 2 demonstration testing was conducted in a larger industrial spreader stoker boiler. In a period of 402 hours, 1702 tons of dRDF were co-fired with coal. An additional 231 hours of coal baseline testing was completed to provide a basis of comparison for the test results.

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This report has been reviewed by the Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendations for use.

FOREWORD

The Environmental Protection Agency (EPA) was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution, and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to preserve and treat public drinking water supplies and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research, a most vital communications link between the researcher and the user community.

In recognition of the fact that more than 50 percent of the roughly 42,000 industrial boilers in the U.S. are coal-fired boilers, the Environmental Protection Agency undertook a project to investigate the technical and environmental implications of using densified (pellet form) refuse derived fuel (dRDF) as a substitute for stoker coal. This report presents the results from co-firing 1702 tons of dRDF when firing at various volumetric blend ratios of coal:dRDF, i.e., 1:1, 1:2, and 1:4.

The investigation specifically addresses the performance of the fuel handling and feeding system, the boiler, and the resulting emissions from each blend firing. Since a spreader stoker-fired (150,000 lb/hr) boiler was co-fired a total of 402 hours without major difficulty, the results are sufficiently encouraging to indicate that co-firing coal and dRDF is a viable alternative to industry.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

ABSTRACT

This study program has the overall objective of evaluating boiler performance and environmental feasibility when combusting densified forms of refuse derived fuels (dRDF) blended with coal and fired in a modern industrial spreader stoker-fired boiler.

The results reported herein represent the second phase of a two-phase evaluation program. Phase 1 was conducted in an institutional spreader stoker heating boiler. During Phase 1 285 tons of dRDF were combusted. The results of that test are reported in EPA Report No. 600/2-80-095. Phase 2 demonstration testing was conducted in a larger industrial spreader stoker boiler. In a period of 402 hours, 1702 tons of dRDF were co-fired with coal. An additional 231 hours of coal baseline testing was completed to provide a basis of comparison for the test results.

The demonstration tests were designed to investigate (1) the material handling characteristics of dRDF after 6 months of storage in an open coal yard, conveying, feeding out of bunkers, and feeding into the boiler; (2) boiler performance, i.e., boiler efficiency, spreader limitations, steam production, combustion properties, slagging, fouling, clinkering, and corrosion; (3) environmental performance, i.e., particulate emissions (size, mass rate, and resistivity), gaseous emissions (SO_x, NO_x, Cl, F, HC), and trace metal emissions (Pb, Cr, Cd, Be, and Zn).

In general, this test clearly demonstrated that co-firing coal and dRDF can be performed with minimal impact on the operational performance of an industrial power plant. The boiler performed well, demonstrating an ability to deliver maximum rated steam capacity with adequate boiler response and fuel burnout at coal:dRDF blends up to 1:4 (by volume). A slight decrease in boiler efficiency (2.5 percent drop) occurred during blend firing. This drop was attributed to the high moisture and hydrogen content of the pellets. There was no significant difference in particulate emissions at either the electrostatic precipitator (ESP) inlet or outlet as a result of firing with blends. ESP collection efficiency was not effected by the blend firing. Increases in heavy metals (namely, lead, cadmium, zinc, chromium) and chloride emissions were noted. Sulfur emissions decreased as the dRDF substitution was increased.

Systems Technology Corporation submitted this report in fulfillment of Contract No. 68-03-2426 sponsored by the Municipal Environmental Research Laboratory of the U.S. Environmental Protection Agency. This report covers the period from January 1, 1978, to July 15, 1980.

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ENGLISH UNITS TO SI UNITS

To convert from	To	Multiply by
in	mm	25.40
in^2	mm^2	645.2
ft	m	0.3048
ft^2	m^2	0.09290
ft^3	m^3	0.02832
lb	kg	0.4536
lb/hr	Mg/s	0.1260
$lb/10^6$ Btu	ng/J	430
Btu	J	1056
Btu/lb	J/kg	0.002328
Btu/hr	W	0.2929
Btu/ft/hr	W/m	0.9609
Btu/ft/hr	J/h/m	3459
$Btu/ft^2/hr$	W/m^2	3.152
$Btu/ft^2/hr$	$J/h/m^2$	11349
$Btu/ft^3/hr$	W/m^3	10.34
$Btu/ft^3/hr$	$J/h/m^3$	37234
psi	Pa	6895
inches H_2O	Pa	249.1
Rankine	Celsius	C = (5/9R) - 273
Fehrenheit	Celsius	C = 5/9(F - 32)
Celsius	Kelvin	K = C + 273
Rankine	Kelvin	K = 5/9R
mm	in	.03937
mm^2	in^2	.00155
m	ft	3.281
m^2	ft^2	10.764
m^3	ft^3	35.315
kg	lb	2.2056
Mg/s	lb/hr	7.937
ng/J	$lb/10^6$ Btu	0.00233

ENGLISH UNITS TO SI UNITS (continued)

To convert from	To	Multiply by
J	Btu	0.000948
J/kg	Btu/lb	4.303
J/h/m	Btu/ft/hr	0.000289
$J/h/m^2$	$Btu/ft^2/hr$	0.0000881
$J/h/m^3$	$Btu/ft^3/hr$	0.0000269
W	Btu/hr	3.414
W/m	Btu/ft/hr	1.041
W/m^2	$Btu/ft^2/hr$	0.317
W/m^3	$Btu/ft^3/hr$	0.0967
Pa	psi	0.000145
Pa	inches H_2O	0.004014
Kelvin	Fahrenheit	F = 1.8K - 460
Celsius	Fahrenheit	F = 1.8C + 32
Fahrenheit	Rankine	R = F + 460
Kelvin	Rankine	R = 1.8K

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APPENDIX A

SITE SELECTION CRITERIA

Prior to initiating this demonstration test, criteria were established with regard to the desired design and operating characteristics of the host facility. The following outline summarizes these criteria.

1. The recommended specifications of the boiler for the demonstration test are:

   a. 500 to 1000 psig operating pressure
   b. 200°F of superheat
   c. 75,000 to 150,000 lb/hr steam
   d. 650,000 Btu/hr/ft^2 grate release rate
   e. Traveling grate with front ash delivery
   f. Tube or welded wall, without refractory

2. Preferred design characteristics of the boiler are:

   a. Superheater behind a screen
   b. Capability of reinjecting the fly carbon to the furnace
   c. A spreader stoker is first choice due to popularity. A gate fed traveling grate may be better than a spreader because it is less apt to cause carryover, however there are more spreaders installed.

3. Preferred plant operating characteristics are:

   a. Two or more boilers operating, so that the test unit can be operated at a full load or at a reduced load. Swings in steam demand should be accommodated by a second boiler in order to permit the test boiler to be held at a constant steam generation rate.

   b. The facility should have an adequate fuel storage area and a fuel handling system with appropriate belt scales to facilitate blending of the coal and dRDF in the desired ratios.

   c. The facility should have scales immediately prior to the boiler distribution chutes to facilitate weighing of the fuel.

4. Preferred plant and owner characteristics are:

   a. The test site should be selected from those industries which are the most likely users of dRDF, i.e., industry, municipal power plants, institutions, and military installations. Heating plants

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are not likely candidates because they lack superheaters and often run at fluctuating and low steam loads.

b. The owner of the test boiler must be a willing and cooperative host.

APPENDIX B

TEST DATA TABLES

The following tables contain the reduced field data and calculated results of the entire test burn conducted at General Electric Company in Erie, Pennsylvania. The columns are grouped according to type of time period each column's results represent. That is, in Columns 1 through 60 each line represents an emissions characterization period of about 2 1/2 hours. Columns 61 through 200 represent data averaged over 1-day periods, and Columns 201 through 272 represent data collected per each recharging of the fuel bunker. The equations of Appendix C are numbered to match these data columns. Each equation illustrates the calculation used to derive its corresponding data column.

TABLE B-1. CORRECTED FUEL USAGE CALCULATIONS 12/12/79
$CF_5 = 1.144$ $CF_3 = 1.036$

Date	Time	#5 Scale	#5 Weighing	#3 Scale	Weighing	Scale 5 ×1.144	Scale 3 ×1.036
3/5	16:15	50	Coal	--	--	57.2	--
3/6	8:30	18.17	Coal	--	--	20.79	--
	12:30	117	Coal	--	--	133.85	--
3/7	8:45	2	Coal	--	--	2.29	--
	9:00	28.54	Coal	--	--	32.65	--
	13:05	153.11	Coal	--	--	175.16	--
3/8		3.07	Coal	--	--	3.51	--
	9:00	40.07	Coal	--	--	45.84	--
		2.76	Coal	--	--	3.16	--
	13:35	172.36	Coal	--	--	197.18	--
3/9		4.77	Coal	--	--	5.46	--
	9:20	38.33	Coal	--	--	43.85	--
	13:38	79.62	Coal	--	--	91.08	--
3/10		24.86	Blend	10.75	dRDF	28.44	11.14
3/12	-	3.00	Blend	0.83	dRDF	3.43	0.86
	11:00	32.08	Blend	6.21	dRDF	36.70	6.43
		33.75	Blend	15.79	dRDF	38.61	16.36
	17:00	91.67	Blend	48.81	dRDF	104.87	50.57
3/13	8:49	175.65	Blend	85.84	dRDF	200.94	88.93
	15:00	73.97	Blend	35.73	dRDF	84.62	37.02
3/14	12:00	231.41	Blend	116.04	dRDF	264.73	120.22
3/15	13:00	228.21	Blend	101.94	dRDF	261.07	105.61
3/16	9:00	154.20	Blend	70.18	dRDF	176.40	72.71
End	23:00						
4/16	17:23	47.89	Blend	24.56	dRDF	54.79	25.44
4/18	9:21	38.97	Blend	23.59	dRDF	44.58	24.44
	13:50	4.66	Coal	--	--	5.33	--
	13:55	1.82	Coal	--	--	2.08	--
	14:17	203.74	Blend	117.67	dRDF	233.08	121.91
4/19	8:30	270.17	Blend	152.65	dRDF	309.07	158.14
	16:00	23.87	Blend	10.69	dRDF	27.31	11.07
4/20	11:30	153.29	Blend	84.31	dRDF	175.36	87.34
4/21	8:00	--	--	3.00	Coal	--	3.11
	8:20	199.45	Blend	74.99	dRDF	228.17	77.69
4/23	5:00	N.A.	Coal	--	--	N.A.	--
	9:00	2.78	Pellets	3.28	Pellets	3.18	3.40
	9:20	34.43	Blend	19.62	Pellets	39.39	20.33
	13:41	255.83	Blend	145.22	Pellets	285.80	147.34
4/24	11:52	259	Blend	145	Pellets	303.16	153.33
4/25	-	10.74	Blend	5.25	Pellets	12.29	5.44
End	11:45						

-- Not measured.
N.A. Not available.

(continued)

TABLE B-1. (continued)

Date	Time	#5 Scale	#5 Weighing	#3 Scale	Weighing	Scale 5 ×1.144	Scale 3 ×1.036
5/4	-	59.66	Blend	30.25	Pellets	68.25	31.34
5/7	14:30	117.78	Blend	67.71	Pellets	134.74	70.15
5/8	13:10	180.91	Blend	98.00	Pellets	206.96	101.53
5/9	10.05	53.69	Blend	29.56	Pellets	61.42	32.62
	15:16	98.94	Blend	55.63	Pellets	113.19	57.63
5/10	8:45	43.38	Blend	24.35	Pellets	49.63	25.23
	13:00	117.10	Blend	44.82	Pellets	133.96	46.43
5/11	6:30	N.A.	Coal	--	--	--	--
	8:55	16.85	Blend	12.12	Pellets	19.28	12.56
	10:08	114.80	Blend	82.42	Pellets	131.33	85.39
5/14	13:00	71.56	Coal	--	--	81.86	--
5/15	9:15	71.29	Coal	77.75	Coal	81.56	--
	14:28	42.34	Coal	--	--	48.44	--
5/16	9:42	37.95	Coal	41.57	Coal	43.41	--
	14:40	75.42	Coal	--	--	86.28	--
5/17	8:55	38.32	Coal	--	--	43.84	--
	13:31	89.05	Coal	--	--	101.87	--
5/18		2.6	Coal	--	--	2.97	--
	8:44	37.56	Coal	--	--	42.97	--

(continued)

TABLE B-1. (continued)

Date	Time	Scale 5 minus Scale 3	Coal tons	dRDF tons	Δt hours	Coal lb/hr	dRDF lb/hr
3/5	16:15	57.2	57.2	--	16.25	7,040	--
3/6	8:30	20.79	20.79	--	4.0	10,395	--
	12:30	133.85	133.85	--	20.50	13,282	--
3/7	8:45	2.29	2.29	--	↑	↑	
	9:00	32.65	32.65	--	4.00	16,325	--
	13:05	175.16	175.16	--	20.00	17,867	--
3/8		3.51	3.51	--	↑	↑	
	9:00	45.84	45.84	--	4.58	21,382	--
		3.16	3.16	--	↑	↑	
	13:35	197.18	197.18	--	19.75	20,521	--
3/9		5.46	5.46	--	↑	↑	
	9:20	43.85	43.85	--	4.30	20,394	--
	13:38	91.08	91.08	--	8.90	20,467	--
3/10		17.30	17.30	11.14	--	--	--
3/12	-	2.57	2.57	0.86	--	--	--
	11:00	30.26	30.26	6.43	6.00	17,503	7,597
		22.25	22.25	16.36	↑	↑	↑
	17:00	54.30	54.30	50.57	15.81	6,866	6,394
3/13	8:49	112.01	112.01	88.93	27.18	11,743	9,268
	15:00	47.60	47.60	37.02	↑	↑	↑
3/14	12:00	144.51	144.51	120.22	25.0	11,561	8,845
3/15	13:00	155.46	155.46	105.61	20.0	15,546	10,561
3/16	9:00	103.69	103.69	72.71	14.0	14,813	10,387
End	23:00						
4/16	17:23	29.35	29.35	25.44	--	--	--
4/18	9:21	20.14	20.14	24.44	4.93	11,169	9,908
	13:50	5.33	5.33	--	↑	↑	↑
	13:55	2.08	2.08	--	↑	↑	↑
	14:17	111.17	111.17	121.91	18.22	12,203	13,382
4/19	8:30	150.92	150.92	158.14	27.0	12,382	12,534
	16:00	16.24	16.24	11.07	↑	↑	↑
4/20	11:30	88.01	88.01	87.34	20.83	8,748	8,385
4/21	8:00	--	3.11	--	↑	↑	↑
	8:20	150.48	150.48	77.69	25.0	12,438	6,487
4/23	5:00	--	5	--	↑	↑	--
	9:00	--	--	3.40	↑	↑	↑
	9:20	19.06	19.06	20.33	4.35	8,763	9,347
	13:41	138.46	138.46	147.34	22.18	12,483	13,284
4/24	11:52	149.83	149.83	153.33	24.00	13,057	13,231
4/25	-	6.85	6.85	5.44	↑	↑	↑
End	11:45						

(continued)

TABLE B-1. (continued)

Date	Time	Scale 5 minus Scale 3	Coal tons	dRDF tons	Δt hours	Coal lb/hr	dRDF lb/hr
5/4	-	36.91	36.91	31.34	--	--	--
5/7	14:30	64.59	64.59	70.15	22.66	5,700	6,191
5/8	13:10	105.43	105.43	101.53	20.92	10,079	9,706
5/9	10:05	30.79	30.79	30.62	5.18	11,888	11,822
	15:16	55.56	55.56	57.63	17.50	6,350	6,586
5/10	8:45	24.40	24.40	25.23	4.25	11,482	11,873
	13:00	87.53	87.53	46.43	17.50	10,003	5,306
5/11	6:30	--	N.A.	--	--	--	--
	8:55	6.72	6.72	12.56	1.22	11,016	20,590
	10:08	45.94	45.94	85.39	10.00	9,188	17,078
5/14	13:00	81.86	81.86	--	20.25	8,085	--
5/15	9:15	81.56	81.56	--	5.25	10,634	--
	14:28	48.44	48.44	--	19.2	↑	--
5/16	9:42	43.41	43.41	--	5.0	17,364	--
	14:40	86.28	86.28	--	18.25	9,455	--
5/17	8:55	43.84	43.84	--	4.58	19,144	--
	13:31	101.87	101.87	--	19.25	10,892	--
5/18		2.97	2.97	--	↑	↑	
	8:44	42.97	42.97	--			

TABLE B-2. EMISSIONS RESULTS

Date	Boiler load by flow meter (10^3 lb/hr)	load (%)	dRDF heat substitution % dRDF	Fly ash reinjection	CO ESP outlet NDIR (%)	O_2 ESP outlet ECC (%)
1	2	2A	3	4	5	6
3/5/AM	74.6	49.7	0	On	6.6	10.7
3/5/PM	72.4	48.3	0	On	6.3	13.2
3/6/AM	62.9	41.9	0	On	4.4	13.0
3/6/PM	64.6	43.1	0	On	5.5	13.7
3/7/AM	114.6	76.4	0	On	7.8	10.8
3/7/PM	113.3	75.5	0	On	8.0	11.8
3/8/AM	144.7	96.5	0	On	8.9	8.5
3/8/PM	142.8	95.2	0	On	8.1	9.0
3/9/AM	140.7	93.8	0	On	8.9	9.1
3/9/PM	144.1	96.1	0	On	8.9	9.8
3/13/AM	99.2	66.1	28	On	7.6	10.5
3/13/PM	108.9	72.6	28	On	8.4	9.9
3/14/AM	99.7	66.5	28	On	7.9	10.9
3/14/PM	106.6	71.1	24	On	8.1	10.6
3/15/AM	113.9	75.9	24	On	6.7*	11.3*
3/15/PM	134.0	89.3	26	On	8.0*	10.7*
3/16/AM	121.6	81.1	25	On	7.8	11.0
3/16/PM	123.3	82.2	25	On	7.8	10.9
4/18/AM	113.9	75.9	30	On	8.3	10.9
4/18/PM	114.7	76.5	33*	On	9.1	10.5
4/19/AM	130.0	86.7	34	On	9.1	9.9
4/19/PM	125.2	83.5	34	On	9.3	9.7
4/20/AM	120.4	80.3	34	On	8.6	11.0
4/20/PM	137.2	91.5	31	On	9.2	10.1
4/21/AM	59.8	39.9	31	On	6.2	15.7
4/21/PM	45.9	30.6	31	On	5.7	16.1
4/23/AM	82.7	55.1	36	On	8.9	10.9
4/23/PM	143.6	95.7	36	On	9.7	9.8
4/24/AM	120.6	80.4	36	Off	9.0	10.6
4/24/PM	143.6	95.7	32	Off	9.2	10.3
4/25/AM	124.5	83.0	32	Off	9.2	9.5

* Assumed value.

(continued)

TABLE B-2. (continued)

Date	Boiler load by flow meter (10^3 lb/hr)	load (%)	dRDF heat substitution % dRDF	Fly ash reinjection	CO ESP outlet NDIR (%)	O_2 ESP outlet ECC (%)
1	2	2A	3	4	5	6
5/7/PM	61.2	40.0	37	On	6.7	12.5
5/8/AM	142.5	95.0	37	On	8.4	11.2
5/8/PM	149.2	99.5	35	On	9.3	10.2
5/9/AM	125.1	83.4	35	Off	9.9	10.0
5/9/PM	155.3	103.5	35	Off	9.1	10.2
5/10/AM	128.9	85.9	37	On	8.5	10.1
5/10/PM	149.2	99.5	23	On	9.2	9.6
5/11/AM	141.9	94.6	51	On	9.1	9.7
5/11/PM	138.2	92.1	51	On	8.6	10.3
5/14/AM	114.1	76.1	51*	On	---	---
5/14/PM	68.7	45.8	0	On	5.6	15.1
5/15/AM	108.4	72.3	0	On	7.8	11.6
5/15/PM	105.0	70.0	0	On	7.6	12.2
5/16/AM	138.1	92.1	0	On	8.4	11.1
5/16/PM	143.4	95.6	0	On	8.5	11.2
5/17/AM	140.0	93.3	0	On	8.9	10.5
5/17/PM	143.2	95.5	0	On	8.9	10.4
5/18/AM	144.1	96.1	0	Off	8.9	9.7
5/18/PM	141.0	94.0	0	Off	8.9	10.5

* Assumed value.

(continued)

TABLE B-2. (continued)

Date	Excess air ESP outlet (%)	CO ESP outlet NDIR at 50% EA (ppm)	NO_x ESP outlet (M-7) 50% EA (ppm)	SO_x ESP outlet (ECC) 50% EA (ppm)	Chlorides ESP inlet 50% EA (ppm)	Fluorides ESP inlet 50% EA (ppm)
1	7	8	9	10	11	12
3/5/AM	96	136	1,620	262	13	0.4
3/5/PM	164	137	---	317	17	0.7
3/6/AM	148	186	---	2,805	30	1.2
3/6/PM	179	221	---	3,289	24	0.8
3/7/AM	101	134	951	3,390	24	0.8
3/7/PM	126	181	---	2,809	66	1.4
3/8/AM	64	134	861	1,744	20	1.1
3/8/PM	70	153	826	2,350	54	1.8
3/9/AM	73	129	872	1,380	28	0.7
3/9/PM	84	129	1,014	2,128	7	0.4
3/13/AM	94	222	169	1,213	35	0.9
3/13/PM	85	242	109	1,685	207	4.2
3/14/AM	103	136	169	1,391	58	1.6
3/14/PM	98	144	243	2,033	138	1.5
3/15/AM	109	---	396	1,838*	32	0.6
3/15/PM	99	---	351	2,600*	89	0.4
3/16/AM	105	484	267	1,576	17.5	0.3
3/16/PM	103	212	235	1,269	60	0.5
4/18/AM	105	118	254	480	216	7.5
4/18/PM	98	306	223	977	179	5.7
4/19/AM	86	140	228	769	198	6.3
4/19/PM	83	139	233	732	188	5.5
4/20/AM	108	135	260	723	206	4.9
4/20/PM	90	182	231	813	178	2.8
4/21/AM	319	580	398	1,897	203	2.8
4/21/PM	354	694	426	1,515	237	3.6
4/23/AM	106	125	195	644	166	2.5
4/23/PM	86	156	251	806	194	1.7
4/24/AM	100	121	274	---	224	4.5
4/24/PM	94	199	291	---	258	4.5
4/25/AM	79	660	196	595	253	4.0

(continued)

TABLE B-2. (continued)

Date	Excess air ESP outlet (%)	CO ESP outlet NDIR at 50% EA (ppm)	NO_x ESP outlet (M-7) 50% EA (ppm)	SO_x ESP outlet (ECC) 50% EA (ppm)	Chlorides ESP inlet 50% EA (ppm)	Fluorides ESP inlet 50% EA (ppm)
1	7	8	9	10	11	12
5/7/PM	142	126	214	515	162	4.0
5/8/AM	112	402	296	451	100	1.7
5/8/PM	92	177	271	627	177	2.7
5/9/AM	90	231	246	622	181	5.0
5/9/PM	92	168	237	627	113	2.3
5/10/AM	89	131	298	365	197	2.5
5/10/PM	81	110	232	702	157	2.3
5/11/AM	83	128	261	439	216	2.3
5/11/PM	93	115	197	335	221	3.7
5/14/AM	---	---	---	---	---	---
5/14/PM	259	705	404	813	147	2.6
5/15/AM	120	106	323	911	109	1.6
5/15/PM	136	111	312	1,052	102	1.6
5/16/AM	109	122	385	681	43	1.7
5/16/PM	112	120	---	635	133	1.8
5/17/AM	97	117	323	419	69	1.8
5/17/PM	95	120	339	416	103	2.0
5/18/AM	82	113	364	484	104	3.0
5/18/PM	97	117	---	637	116	1.7

(continued)

TABLE B-2. (continued)

Date	Particulate ESP inlet 50% EA (gr/dscf)	Particulate ESP outlet 50% EA (gr/dscf)	Particle size ESP inlet $D_{36.79}$ (μm)	Size distribution ESP inlet R (slope)	Particle size ESP outlet $D_{36.79}$ (μm)
1	13	14	15	15A	16
3/5/AM	1.271	*	18	.65	*
3/5/PM	---	*	29	1.05	11.2
3/6/AM	0.997	*	10	.47	*
3/6/PM	1.158	*	38	.68	*
3/7/AM	0.681	*	45	.74	*
3/7/PM	1.616	*	29	.83	*
3/8/AM	1.004	0.323	52	.64	10
3/8/PM	2.233	0.141	75	.54	.05
3/9/AM	1.259	0.237	16	.80	4.8
3/9/PM	0.467	0.241	90	.49	9.5
3/13/AM	0.815	*	20		5.1
3/13/PM	1.152	*	46	.47	*
3/14/AM	0.546	*	27	.75	*
3/14/PM	1.619	*	46	.43	*
3/15/AM	0.487	---	16	.62	3.6
3/15/PM	1.699	0.063	46	.68	1.7
3/16/AM	0.288	0.264	18	.64	7.0
3/16/PM	0.678	0.385	19	.55	1.1
4/18/AM	1.400	*	67	.56	*
4/18/PM	1.214	*	210	.77	*
4/19/AM	1.666	0.019	32	.68	4.0
4/19/PM	1.410	0.012	85	.62	5.4
4/20/AM	1.388	0.018	14	.82	1.9
4/20/PM	1.771	0.021	16	.76	2.1
4/21/AM	1.742	*	26	.76	*
4/21/PM	2.041	*			*
4/23/AM	1.156	*	67	.54	*
4/23/PM	1.413	*	24	.9	*
4/24/AM	0.847	0.014	25	.67	6.0
4/24/PM	1.088	0.012	60	.80	6.0
4/25/AM	0.849	0.018	100	.63	14.5

(continued)

TABLE B-2. (continued)

Date	Particulate ESP inlet 50% EA (gr/dscf)	Particulate ESP outlet 50% EA (gr/dscf)	Particle size ESP inlet $D_{36.79}$ (µm)	Size distribution ESP inlet R (slope)	Particle size ESP outlet $D_{36.79}$ (µm)
1	13	14	15	15A	16
5/7/PM	0.457	*	13	.74	*
5/8/AM	0.850	0.110	87	.53	5.8
5/8/PM	---	0.045	6.0	.52	5.7
5/9/AM	---	---	70	.46	.59
5/9/PM	0.767	0.026	70	.60	7.0
5/10/AM	1.497	0.036	63	.88	4.4
5/10/PM	0.770	0.097	80	.75	4.7
5/11/AM	1.398	0.477	68	.47	.25
5/11/PM	1.225	0.146	64	.63	3.2
5/14/AM	---	*	---	---	*
5/14/PM	1.485	*	9.5	.54	*
5/15/AM	1.670	*	70	.45	*
5/15/PM	1.882	*	47	.84	*
5/16/AM	1.819	0.082	58	.77	5.5
5/16/PM	2.152	0.086	29	.76	5.0
5/17/AM	1.588	0.064	39	.67	6.0
5/17/PM	1.491	0.071	40	.70	3.7
5/18/AM	1.485	0.066	101	.79	5.0
5/18/PM	1.217	0.059	17.4	.76	5.8

(continued)

TABLE B-2. (continued)

Date	Particle size ESP outlet R (slope)	Particulate emission ESP inlet (lb/ 10^6 Btu)	Particulate emission ESP outlet (lb/ 10^6 Btu)	NO_x emission ESP outlet (lb/ 10^6 Btu)	SO_x emission ESP outlet (lb/ (10^6 Btu)
1	16A	17	18	19	20
3/5/AM	*	2.79	*	2.959	.666
3/5/PM	.76	---	*	---	.794
3/6/AM	*	2.24	*	---	7.307
3/6/PM	*	2.54	*	---	8.340
3/7/AM	*	1.48	*	1.715	8.505
3/7/PM	*	3.44	*	---	6.942
3/8/AM	.95	2.18	0.70	1.555	4.302
3/8/PM		4.87	0.31	1.499	5.934
3/9/AM	.68	2.72	0.51	1.569	3.453
3/9/PM	.80	1.00	0.52	1.813	5.293
3/13/AM	.76	1.79	*	.309	3.085
3/13/PM	*	2.51	*	.198	4.250
3/14/AM	*	1.19	*	.307	3.516
3/14/PM	*	3.51	*	.438	5.099
3/15/AM	.46	1.07	---	.727	4.697
3/15/PM	.40	3.69	0.14	.634	6.537
3/16/AM	1.04	0.63	0.57	.483	3.963
3/16/PM	.48	1.48	0.84	.427	3.206
4/18/AM	*	2.97	*	.448	1.177
4/18/PM	*	2.56	*	.392	2.387
4/19/AM	.46	3.54	0.04	.403	1.890
4/19/PM	.56	2.99	0.03	.411	1.796
4/20/AM	.43	2.92	0.04	.455	1.761
4/20/PM	.38	3.75	0.04	.407	1.991
4/21/AM	*	3.48	*	.496	4.392
4/21/PM	*	4.07	*	.707	3.499
4/23/AM	*	2.44	*	.342	1.573
4/23/PM	*	2.97	*	.439	1.960
4/24/AM	.59	1.79	0.03	.481	---
4/24/PM	.52	2.31	0.03	.513	---
4/25/AM	.87	1.81	0.04	.349	1.472

(continued)

TABLE B-2. (continued)

Date	Particle size ESP outlet R (slope)	Particulate emission ESP inlet (lb/ 10^6 Btu)	Particulate emission ESP outlet (lb/ 10^6 Btu)	NO_x emission ESP outlet (lb/ 10^6 Btu)	SO_x emission ESP outlet (lb/ (10^6 Btu)
1	16A	17	18	19	20
5/7/PM	*	0.96	*	.375	1.258
5/8/AM	.64	1.77	0.23	.514	.954
5/8/PM	.65	--	0.09	.470	1.514
5/9/AM	.59	---	---	.422	1.486
5/9/PM	.63	1.60	0.05	.411	1.514
5/10/AM	.77	3.14	0.08	.520	.886
5/10/PM	.76	1.62	0.20	.406	1.708
5/11/AM	---	2.90	0.99	.451	1.054
5/11/PM	.59	2.54	0.30	.340	.804
5/14/AM	*	---	*	---	---
5/14/PM	*	3.11	*	.705	1.972
5/15/AM	*	3.55	*	.571	2.241
5/15/PM	*	4.00	*	.552	2.590
5/16/AM	.96	3.88	0.17	.683	1.681
5/16/PM	.78	4.57	0.18	---	1.561
5/17/AM	.64	3.39	0.14	.573	1.034
5/17/PM	.78	3.17	0.15	.600	1.025
5/18/AM	.60	3.18	0.14	.649	1.201
5/18/PM	.73	2.59	0.13	---	1.572

(continued)

TABLE B-2. (continued)

Date	CO emission (lb/10^6 Btu)	Cl^- emission (lb/10^6 Btu)	F^- emission (lb/10^6 Btu)	E_{ASH} (%)	E_{SO_2} (%)	E_{NO_x} (%)
1	20A	20B	20C	20D	20E	20F
3/5/AM	.151	.017	.00032	22	10	100
3/5/PM	.150	.017	.00047	--	12	--
3/6/AM	.212	.041	.00080	18	108	--
3/6/PM	.245	.037	.00071	20	124	--
3/7/AM	.147	.032	.00059	12	126	58
3/7/PM	.196	.086	.00097	27	103	--
3/8/AM	.147	.027	.00077	17	65	53
3/8/PM	.169	.073	.00127	38	88	51
3/9/AM	.141	.037	.00049	22	51	53
3/9/PM	.140	.009	.00025	8	78	61
3/13/AM	.247	.047	.00063	7	36	10
3/13/PM	.267	.277	.00298	11	49	7
3/14/AM	.150	.078	.00110	5	41	10
3/14/PM	.158	.183	.00099	15	57	15
3/15/AM	---	.043	.00044	5	53	25
3/15/PM	---	.119	.00026	16	74	21
3/16/AM	.532	.023	.00018	3	45	16
3/16/PM	.234	.081	.00035	6	36	14
4/18/AM	.127	.282	.00520	24	42	16
4/18/PM	.327	.232	.00390	20	90	14
4/19/AM	.150	.259	.00437	28	69	15
4/19/PM	.149	.245	.00379	24	66	15
4/20/AM	.144	.266	.00333	24	65	17
4/20/PM	.195	.232	.00192	30	72	15
4/21/AM	.587	.249	.00182	28	161	18
4/21/PM	.701	.291	.00236	33	129	26
4/23/AM	.134	.215	.00169	19	59	13
4/23/PM	.166	.250	.00119	23	74	16
4/24/AM	.129	.291	.00292	14	--	18
4/24/PM	.214	.003	.00303	19	--	18
4/25/AM	.649	.003	.00281	15	54	13

(continued)

TABLE B-2. (continued)

Date	CO emission (lb/ 10^6 Btu)	Cl^- emission (lb/ 10^6 Btu)	F^- emission (lb/ 10^6 Btu)	E_{ASH} (%)	E_{SO_2} (%)	E_{NO_x} (%)
1	20A	20B	20C	20D	20E	20F
5/7/PM	.135	.210	.00267	9	66	14
5/8/AM	.425	.128	.00113	16	49	19
5/8/PM	.187	.227	.00179	--	78	17
5/9/AM	.241	.230	.00333	--	77	15
5/9/PM	.117	.145	.00495	15	78	15
5/10/AM	.139	.254	.00172	29	47	19
5/10/PM	.177	.203	.00157	17	78	14
5/11/AM	.134	.275	.00412	23	67	19
5/11/PM	.121	.282	.00252	20	50	14
5/14/AM	---	---	---	--	--	--
5/14/PM	.748	.189	.00179	41	63	22
5/15/AM	.114	.142	.00112	47	71	18
5/15/PM	.120	.133	.00109	53	82	17
5/16/AM	.132	.057	.00116	51	54	21
5/16/PM	.113	.174	.00127	60	50	--
5/17/AM	.126	.091	.00127	45	33	18
5/17/PM	.129	.135	.00135	42	33	19
5/18/AM	.123	.138	.00211	42	38	20
5/18/PM	.126	.152	.00118	34	50	--

(continued)

TABLE B-2. (continued)

Date	ESP-CO flow rate (lb/hr)	H_2O measured ESP inlet (%)	H_2O* measured ESP outlet (%)	Cl^- ESP inlet (ppm)	Cl^- ESP outlet (ppm)	F^- ESP inlet (ppm)
1	21	22	23	24	25	26
3/5/AM	17.1	3.52	*	9.78	*	0.345
3/5/PM	16.5	2.52	*	9.45	*	0.379
3/6/AM	20.3	2.90	*	18.02	*	0.665
3/6/PM	24.1	2.55	*	14.76	*	0.535
3/7/AM	25.6	2.33	*	18.05	*	0.626
3/7/PM	33.5	3.62	*	43.40	*	0.928
3/8/AM	32.4	2.33	4.18	18.84	85.93	0.996
3/8/PM	36.7	2.45	4.69	47.86	101.74	1.587
3/9/AM	30.1	2.24	4.85	24.36	125.68	0.603
3/9/PM	30.8	1.34	3.31	5.45	129.04	0.289
3/13/AM	37.2	4.57	*	26.99	*	0.679
3/13/PM	44.1	6.70	*	168.22	*	3.420
3/14/AM	22.8	3.32	*	43.02	*	1.151
3/14/PM	25.6	6.46	*	104.25	*	1.059
3/15/AM	---	3.01	---	22.90	---	0.444
3/15/PM	---	7.01	1.69	66.86	4.70	0.281
3/16/AM	98.5	1.35	6.07	12.80	20.52	0.189
3/16/PM	43.8	1.92	5.71	44.64	33.34	0.367
4/18/AM	21.9	7.44	*	157.8	*	5.5
4/18/PM	57.0	7.01	*	135.3	*	4.3
4/19/AM	29.7	6.99	5.78	160.3	117.1	5.1
4/19/PM	28.4	6.44	7.20	154.0	161.4	4.5
4/20/AM	26.3	7.56	7.93	148.0	166.0	3.5
4/20/PM	40.6	7.05	7.21	140.3	141.0	2.2
4/21/AM	53.3	3.62	*	72.7	*	1.0
4/21/PM	49.2	3.71	*	78.3	*	1.2
4/23/AM	16.8	6.34	*	121.0	*	1.8
4/23/PM	36.2	7.30	*	156.1	*	1.4
4/24/AM	23.7	7.18	7.52	168.6	186.9	3.2
4/24/PM	46.6	7.60	7.37	193.8	240.3	3.4
4/25/AM	11.3	8.09	8.25	212.7	235.3	3.4

* Moisture increase from inlet to outlet attributed to measurement error.

(continued)

TABLE B-2. (continued)

Date	ESP-CO flow rate (lb/hr)	H_2O measured ESP inlet (%)	H_2O measured ESP outlet (%)	Cl^- ESP inlet (ppm)	Cl^- ESP outlet (ppm)	F^- ESP inlet (ppm)
1	21	22	23	24	25	26
5/7/PM	12.5	5.28	*	100.41	*	2.41
5/8/AM	91.9	3.47	6.38	70.81	163.07	1.18
5/8/PM	42.4	6.35	6.87	138.41	166.77	2.06
5/9/AM	45.9	6.91	7.48	142.81	171.86	3.9
5/9/PM	41.9	5.05	7.86	88.31	181.72	5.7
5/10/AM	27.3	6.75	6.98	156.14	162.99	2.0
5/10/PM	26.5	6.31	7.18	129.55	111.66	1.9
5/11/AM	29.0	8.33	8.31	176.69	101.03	5.0
5/11/PM	25.3	7.53	8.39	171.39	149.54	2.9
5/14/AM	---	4.86	*	88.10	*	1.0
5/14/PM	78.1	3.51	*	61.33	*	1.1
5/15/AM	18.8	4.53	*	73.95	*	1.1
5/15/PM	19.1	4.05	*	64.96	*	1.0
5/16/AM	27.6	1.94	3.71	31.33	64.67	1.2
5/16/PM	28.1	4.28	4.01	94.30	93.99	1.3
5/17/AM	26.9	3.50	4.78	52.96	84.34	1.4
5/17/PM	28.1	4.33	4.70	79.08	70.49	1.5
5/18/AM	26.8	5.00	5.23	86.28	87.62	2.5
5/18/PM	27.1	5.04	5.07	88.61	80.90	1.3

(continued)

TABLE B-2. (continued)

Date	F^- outlet (ppm)	SO_x ESP inlet (ppm)	SO_x ESP outlet (ppm)	Velocity ESP inlet (fpm)	Velocity ESP outlet (fpm)	Flow ESP inlet (SCFM)
1	27	28	29	30	31	32
3/5/AM	*	1,622	*	1,255	*	50,181
3/5/PM	*	747	*	1,237	*	50,665
3/6/AM	*	1,547	*	1,286	*	52,893
3/6/PM	*	1,421	*	1,288	*	52,571
3/7/AM	*	1,073	*	1,731	*	68,732
3/7/PM	*	1,447	*	1,834	*	70,974
3/8/AM	0.776	656	1,529	2,127	2,308	81,799
3/8/PM	1.010	1,739	1,839	2,125	2,268	81,765
3/9/AM	0.710	530	947	2,009	2,245	78,103
3/9/PM	1.198	180	1,699	2,143	2,383	82,645
3/13/AM	*	1,040	*	1,559	*	62,148
3/13/PM	*	1,502	*	1,831	*	72,819
3/14/AM	*	601	*	1,747	*	69,152
3/14/PM	*	1,794	*	1,856	*	72,633
3/15/AM	---	681	---	1,894	---	75,951
3/15/PM	0.075	2,183	568	2,120	2,185	85,522
3/16/AM	0.311	222	1,598	1,989	2,071	78,523
3/16/PM	1.070	438	1,049	2,118	2,243	83,908
4/18/AM	*	769	*	1,692	*	67,332
4/18/PM	*	917	*	1,773	*	70,887
4/19/AM	4.7	890	627	1,960	2,144	77,616
4/19/PM	6.1	820	826	2,014	1,988	78,742
4/20/AM	2.77	738	748	1,877	2,108	74,416
4/20/PM	4.0	791	1,138	2,000	2,178	79,853
4/21/AM	*	623	*	1,223	*	51,200
4/21/PM	*	584	*	1,226	*	51,074
4/23/AM	*	713	*	1,398	*	58,291
4/23/PM	*	968	*	2,076	*	83,393
4/24/AM	4.5	781	805	1,911	2,129	76,080
4/24/PM	5.0	958	974	1,961	2,271	77,614
4/25/AM	5.0	808	803	1,863	2,076	75,206

(continued)

TABLE B-2. (continued)

Date	F^- outlet (ppm)	SO_x ESP inlet (ppm)	SO_x ESP outlet (ppm)	Velocity ESP inlet (fpm)	Velocity ESP outlet (fpm)	Flow ESP inlet (SCFM)
1	27	28	29	30	31	32
5/7/PM	*	589	*	1,151	*	47,477
5/8/AM	3.39	244	508	2,191	2,291	86,562
5/8/PM	6.17	679	649	2,127	2,294	84,831
5/9/AM	1.8	580	576	2,089	2,256	83,927
5/9/PM	6.1	303	536	2,126	2,312	85,008
5/10/AM	7.0	560	530	2,120	2,322	77,828
5/10/PM	3.0	788	849	2,095	2,245	82,575
5/11/AM	3.3	654	638	1,937	1,973	75,902
5/11/PM	2.0	433	373	2,050	2,145	80,237
5/14/AM	*	420	*	2,072	*	82,375
5/14/PM	*	558	*	1,603	*	64,260
5/15/AM	*	735	*	2,023	*	78,383
5/15/PM	*	850	*	1,961	*	77,222
5/16/AM	0.9	343	808	2,441	2,692	95,879
5/16/PM	1.2	668	642	2,396	2,645	94,330
5/17/AM	1.3	548	765	2,120	2,219	84,183
5/17/PM	1.3	705	638	2,130	2,293	84,090
5/18/AM	1.3	846	739	2,018	2,139	80,110
5/18/PM	1.2	768	717	2,082	2,250	82,064

(continued)

TABLE B-2. (continued)

Date	Flow ESP outlet (SCFM)	Temp.* ESP inlet (°F)	Temp. ESP outlet (°F)	Particulate rate ESP inlet (lb/hr)	Particulate rate ESP outlet (lb/hr)	NO_x rate ESP outlet ECC (lb/hr)
1	33	34	35	36	37	38
3/5/AM	*	382	*	402.3	*	335
3/5/PM	*	362	*	N/A	*	---
3/6/AM	*	358	*	265.9	*	---
3/6/PM	*	364	*	273.2	*	---
3/7/AM	*	385	*	295.8	*	297
3/7/PM	*	395	*	627.1	*	---
3/8/AM	80,018	407	408	630.4	194.5	342
3/8/PM	78,540	409	409	1,350.4	79.8	325
3/9/AM	78,010	406	412	716.3	131.0	335
3/9/PM	81,866	413	422	265.0	132.9	396
3/13/AM	*	386	*	321.1	*	46.6
3/13/PM	*	388	*	545.2	*	32.7
3/14/AM	*	392	*	230.5	*	46.5
3/14/PM	*	390	*	713.9	*	71.0
3/15/AM	---	381	---	221.2	---	125.8
3/15/PM	79,235	376	377	870.4	31.8	129
3/16/AM	75,509	403	381	139.2	116.9	89.2
3/16/PM	81,490	400	384	354.1	187.7	79.9
4/18/AM	*	395	*	545.5	*	77.5
4/18/PM	*	391	*	519.3	*	68.1
4/19/AM	75,269	396	409	831.1	9.2	75.9
4/19/PM	68,920	407	420	729.6	5.3	78.1
4/20/AM	74,433	395	404	588.4	7.8	83.3
4/20/PM	77,988	389	392	886.9	10.4	84.7
4/21/AM	*	353	*	264.0	*	60.1
4/21/PM	*	357	*	283.8	*	49.2
4/23/AM	*	356	*	394.8	*	38.5
4/23/PM	*	387	*	754.7	*	95.7
4/24/AM	76,283	390	390	385.5	6.4	88.2
4/24/PM	80,519	395	399	518.3	6.0	113
4/25/AM	75,515	374	373	422.6	8.8	65.9

* Temperature accuracy estimated ±2 percent.

(continued)

TABLE B-2. (continued)

Date	Flow ESP outlet (SCFM)	Temp. ESP inlet (°F)	Temp. ESP outlet (°F)	Particulate rate ESP inlet (lb/hr)	Particulate rate ESP outlet (lb/hr)	NO_x rate ESP outlet ECC (lb/hr)
1	33	34	35	36	37	38
5/7/PM	*	359	*	109.4	*	84.1
5/8/AM	82,923	391	376	431.8	51.7	170
5/8/PM	83,031	383	376	---	23.2	247
5/9/AM	81,475	378	379	---	N/A	203
5/9/PM	82,612	382	388	417.7	13.2	257
5/10/AM	82,273	394	394	792.1	18.5	125
5/10/PM	79,545	393	394	421.7	50.9	278
5/11/AM	70,154	398	391	683.4	215.4	163
5/11/PM	75,622	399	398	598.7	67.3	121
5/14/AM	*	388	*	562.3	*	---
5/14/PM	*	381	*	330.0	*	148
5/15/AM	*	411	*	728.5	*	266
5/15/PM	*	397	*	761.1	*	297
5/16/AM	94,944	403	405	1,039.0	46.3	153
5/16/PM	94,488	401	394	1,181.0	47.3	244
5/17/AM	78,843	398	403	843.6	31.5	158
5/17/PM	81,472	403	403	790.6	36.4	161
5/18/AM	76,862	394	389	800.3	33.9	189
5/18/PM	79,632	400	402	620.2	29.0	242

(continued)

TABLE B-2. (continued)

Date	SO_x rate ESP outlet (lb/hr)	CL^- rate ESP inlet (lb/hr)	Fluoride rate ESP inlet (lb/hr)	Opacity economizer outlet (%)	Primary voltage ESP Section A (AC-V)
1	39	40	41	42	43
3/5/AM	75.3	1.96	.037	12	280
3/5/PM	87.3	2.43	.052	6	290
3/6/AM	699	3.93	.077	12	290
3/6/PM	818	3.63	.070	18	280
3/7/AM	1,477	5.60	.103	14	290
3/7/PM	1,194	14.80	.168	15	310
3/8/AM	963	6.02	.168	26	250
3/8/PM	1,287	15.74	.276	23	250
3/9/AM	737	7.95	.104	25	250
3/9/PM	1,158	1.94	.054	22	250
3/13/AM	466	7.10	.095	7	275
3/13/PM	701	45.75	.492	7	260
3/14/AM	532	11.79	.167	7	280
3/14/PM	827	29.67	.160	15	275
3/15/AM	813	7.47	.077	13	250
3/15/PM	1,330	24.18	.054	23	260
3/16/AM	733	4.33	.034	21	255
3/16/PM	600	15.13	.066	15	255
4/18/AM	204	48.74	.899	15	265
4/18/PM	415	40.37	.679	39	260
4/19/AM	373	51.20	.862	29	250
4/19/PM	342	46.51	.720	29	250
4/20/AM	323	48.68	.609	25	245
4/20/PM	415	48.29	.401	40	245
4/21/AM	399	22.65	.165	43	225
4/21/PM	244	20.26	.164	50	250
4/23/AM	197	34.25	.270	44	240
4/23/PM	428	54.55	.259	55	250
4/24/AM	---	53.32	.536	--	250
4/24/PM	---	71.10	.660	12	250
4/25/AM	278	62.90	.532	15	255

(continued)

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TABLE B-2. (continued)

Date	SO_x rate ESP outlet (lb/hr)	CL^- rate ESP inlet (lb/hr)	Fluoride rate ESP inlet (lb/hr)	Opacity economizer outlet (%)	Primary voltage ESP Section A (AC-V)
1	39	40	41	42	43
5/7/PM	36.8	19.48	.247	9	300
5/8/AM	52.3	27.73	.245	33	250
5/8/PM	96.8	51.51	.406	30	245
5/9/AM	82.2	43.73	.632	15	250
5/9/PM	64.3	34.21	1.169	22	250
5/10/AM	93.7	49.71	.337	21	250
5/10/PM	86.6	45.89	.356	26	245
5/11/AM	112	59.23	.887	21	250
5/11/PM	111	59.17	.530	15	265
5/14/AM	---	27.82	.166	18	255
5/14/PM	37.2	19.72	.187	16	275
5/15/AM	44.2	23.39	.184	25	250
5/15/PM	40.0	21.26	.173	30	245
5/16/AM	22.3	11.97	.243	33	245
5/16/PM	71.3	37.83	.276	30	250
5/17/AM	36.2	19.35	.271	27	240
5/17/PM	55.2	29.26	.294	23	240
5/18/AM	56.5	30.11	.462	22	245
5/18/PM	61.3	32.60	.253	20	230

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TABLE B-2. (continued)

Date	Primary current ESP Section A (AC-Amp)	Field 1 current ESP Section A (DC-Amp)	Field 2 current ESP Section A (DC-Amp)	Spark rate ESP Section A (min^{-1})	Primary voltage ESP Section B (AC-V)
1	44	45	46	47	48
3/5/AM	70	.19	.19	35	285
3/5/PM	70	.19	.19	40	280
3/6/AM	70	.19	.19	50	290
3/6/PM	65	.18	.18	45	290
3/7/AM	70	.20	.20	45	300
3/7/PM	65	.22	.22	40	300
3/8/AM	50	.14	.14	45	290
3/8/PM	60	.16	.16	35	300
3/9/AM	55	.15	.15	30	300
3/9/PM	55	.16	.16	30	290
3/13/AM	70	.19	.19	40	300
3/13/PM	60	.18	.18	50	300
3/14/AM	70	.20	.20	40	300
3/14/PM	65	.20	.20	50	300
3/15/AM	50	.13	.13	35	300
3/15/PM	45	.12	.12	25	300
3/16/AM	50	.13	.13	30	300
3/16/PM	50	.15	.15	40	300
4/18/AM	60	.20	.20	45	300
4/18/PM	60	.18	.18	30	290
4/19/AM	60	.19	.19	40	300
4/19/PM	60	.18	.18	40	300
4/20/AM	55	.15	.15	15	260
4/20/PM	55	.15	.15	20	250
4/21/AM	55	.15	.15	4	295
4/21/PM	55	.15	.15	5	290
4/23/AM	60	.16	.16	5	300
4/23/PM	55	.15	.15	20	295
4/24/AM	60	.15	.15	15	290
4/24/PM	55	.15	.15	30	300
4/25/AM	55	.16	.16	35	280

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TABLE B-2. (continued)

Date	Primary current ESP Section A (AC-Amp)	Field 1 current ESP Section A (DC-Amp)	Field 2 current ESP Section A (DC-Amp)	Spark rate ESP Section A (min^{-1})	Primary voltage ESP Section B (AC-V)
1	44	45	46	47	48
5/7/PM	90	.27	.27	40	320
5/8/AM	55	.17	.17	50	300
5/8/PM	45	.15	.15	50	260
5/9/AM	55	.16	.16	70	315
5/9/PM	60	.16	.16	60	325
5/10/AM	55	.16	.16	50	315
5/10/PM	55	.16	.16	50	310
5/11/AM	65	.20	.20	60	310
5/11/PM	60	.19	.19	65	320
5/14/AM	55	.18	.18	60	300
5/14/PM	75	.24	.24	55	250
5/15/AM	60	.18	.18	45	270
5/15/PM	60	.18	.18	45	250
5/16/AM	60	.18	.18	50	250
5/16/PM	55	.18	.18	55	240
5/17/AM	50	.17	.17	35	260
5/17/PM	50	.16	.16	35	260
5/18/AM	60	.16	.16	45	250
5/18/PM	55	.17	.17	45	245

(continued)

TABLE B-2. (continued)

Date	Primary current ESP Section B (AC-Amp)	Field 1 current ESP Section B (DC-Amp)	Field 2 current ESP Section B (DC-Amp)	Spark rate ESP Section B (min^{-1})	Excess air correction factor (to 50%)
1	49	50	51	52	53
3/5/AM	85	.24	.24	40	1.31
3/5/PM	80	.22	.22	60	1.76
3/6/AM	80	.23	.23	50	1.65
3/6/PM	85	.23	.23	50	1.86
3/7/AM	90	.26	.26	5	1.34
3/7/PM	85	.26	.26	15	1.51
3/8/AM	90	.26	.26	20	1.09
3/8/PM	90	.25	.25	20	1.13
3/9/AM	90	.26	.26	10	1.15
3/9/PM	90	.26	.26	20	1.23
3/13/AM	95	.24	.24	5	1.29
3/13/PM	95	.28	.28	0	1.23
3/14/AM	90	.28	.28	5	1.35
3/14/PM	90	.28	.28	5	1.32
3/15/AM	90	.26	.26	30	1.39
3/15/PM	90	.26	.26	30	1.33
3/16/AM	95	.28	.28	15	1.37
3/16/PM	90	.28	.28	10	1.35
4/18/AM	90	.28	.28	5	1.37
4/18/PM	85	.23	.23	25	1.32
4/19/AM	95	.28	.28	5	1.24
4/19/PM	95	.28	.28	2	1.22
4/20/AM	70	.20	.20	3	1.39
4/20/PM	65	.18	.18	2	1.27
4/21/AM	90	.25	.25	5	2.79
4/21/PM	85	.25	.25	5	3.03
4/23/AM	90	.24	.24	3	1.37
4/23/PM	90	.24	.24	5	1.24
4/24/AM	90	.24	.24	5	1.33
4/24/PM	90	.24	.24	10	1.29
4/25/AM	90	.24	.24	15	1.19

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TABLE B-2. (continued)

Date	Primary current ESP Section B (AC-Amp)	Field 1 current ESP Section B (DC-Amp)	Field 2 current ESP Section B (DC-Amp)	Spark rate ESP Section B (min^{-1})	Excess air correction factor (to 50%)
1	49	50	51	52	53
5/7/PM	80	.22	.22	20	1.61
5/8/AM	70	.19	.19	60	1.41
5/8/PM	60	.16	.16	40	1.28
5/9/AM	70	.22	.22	35	1.27
5/9/PM	75	.21	.21	20	1.28
5/10/AM	70	.21	.21	40	1.26
5/10/PM	75	.21	.21	30	1.21
5/11/AM	80	.22	.22	15	1.22
5/11/PM	75	.21	.21	20	1.29
5/14/AM	70	.20	.20	45	---
5/14/PM	50	.14	.14	35	2.39
5/15/AM	60	.16	.16	45	1.47
5/15/PM	45	.12	.12	45	1.57
5/16/AM	50	.14	.14	55	1.39
5/16/PM	40	.10	.10	40	1.41
5/17/AM	55	.14	.14	45	1.31
5/17/PM	50	.13	.13	40	1.30
5/18/AM	50	.13	.13	40	1.21
5/18/PM	45	.11	.11	40	1.31

(continued)

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TABLE B-2. (continued)

Date	ESP power consump. (KVA)	ESP pressure (in H_2O)	ESP efficiency (%)	M-5 start time	M-5 end time
1	54	55	56	57	58
3/5/AM	43.8	- 7.4	*	0857	1114
3/5/PM	42.7	- 7.3	*	1258	1513
3/6/AM	43.5	- 8.0	*	0834	1051
3/6/PM	42.9	- 8.0	*	1210	1530
3/7/AM	47.3	-10.5	*	1000	1223
3/7/PM	45.7	-10.5	*	1430	1656
3/8/AM	38.6	-10.7	67.9	0904	1210
3/8/PM	42.0	-10.7	93.6	1333	1604
3/9/AM	40.8	-10.7	81.3	0923	1144
3/9/PM	39.9	-10.7	48.0	1303	1524
3/13/AM	47.8	- 9.3	*	0900	1118
3/13/PM	44.1	-10.2	*	1345	1635
3/14/AM	46.6	- 9.3	*	0930	1115
3/14/PM	44.9	- 9.3	*	1345	1646
3/15/AM	39.5	-10.3	---	0901	---
3/15/PM	38.7	- 9.8	96.2	1512	1745
3/16/AM	41.3	-10.7	9.5	0948	1320
3/16/PM	39.8	-10.7	43.2	1420	1744
4/18/AM	42.9	- 9.7	*	1019	1245
4/18/PM	40.3	-10.4	*	1346	1606
4/19/AM	43.5	-10.5	98.9	0934	1214
4/19/PM	43.5	-10.5	99.0	1414	1649
4/20/AM	31.7	-10.5	98.6	0912	1136
4/20/PM	29.7	-10.6	98.9	1342	1603
4/21/AM	38.9	- 8.0	*	0853	1211
4/21/PM	38.4	- 7.8	*	1323	1545
4/23/AM	41.4	-10.1	*	0953	1216
4/23/PM	40.3	-10.5	*	1353	1617
4/24/AM	41.1	-10.5	98.3	0855	1117
4/24/PM	40.8	-10.5	98.7	1333	1556
4/25/AM	39.2	-10.5	97.8	0831	1021

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(PREVIOUSLY CIN EPA FORM 287)
TYPING GUIDE SHEET

TABLE B-2. (continued)

Date	ESP power consump. (KVA)	ESP pressure (in H_2O)	ESP efficiency (%)	M-5 start time	M-5 end time
1	54	55	56	57	58
5/7/PM	52.6	- 8.8	*	1442	1638
5/8/AM	34.8	-10.6	87.0	0920	1116
5/8/PM	26.6	-10.7	---	1435	1631
5/9/AM	35.8	-10.6	---	0920	1116
5/9/PM	39.4	-10.5	96.9	1305	1501
5/10/AM	35.8	-10.7	97.5	1001	1157
5/10/PM	36.7	-10.6	87.7	1400	---
5/11/AM	41.1	-10.8	65.9	1000	1230
5/11/PM	39.9	-10.7	88.2	1355	1625
5/14/AM	35.0	-10.3	*	0917	1139
5/14/PM	33.1	- 9.9	*	1330	1551
5/15/AM	31.2	-10.2	*	0847	1105
5/15/PM	26.0	-10.1	*	1203	1436
5/16/AM	27.2	-10.8	95.5	0915	1131
5/16/PM	23.4	-10.7	96.1	1234	1511
5/17/AM	26.3	-10.5	95.9	0832	1051
5/17/PM	25.0	-10.6	95.3	1146	1400
5/18/AM	27.2	-10.7	95.6	0829	1049
5/18/PM	23.7	-10.6	95.0	1205	1459

(continued)

TABLE B-2. (continued)

Date	F-factor power (Fd)	Calculated EPS inlet flow (DSCFM)
1	59	60
3/5/AM	9,823	3.80×10^4
3/5/PM	9,823	4.87×10^4
3/6/AM	9,823	4.14×10^4
3/6/PM	9,823	4.66×10^4
3/7/AM	9,823	5.89×10^4
3/7/PM	9,823	6.47×10^4
3/8/AM	9,823	6.06×10^4
3/8/PM	9,823	6.24×10^4
3/9/AM	9,823	6.19×10^4
3/9/PM	9,823	6.75×10^4
3/13/AM	9,871	4.99×10^4
3/13/PM	9,871	5.16×10^4
3/14/AM	9,871	5.20×10^4
3/14/PM	9,864	5.40×10^4
3/15/AM	9,864	6.19×10^4
3/15/PM	9,867	6.86×10^4
3/16/AM	9,866	6.42×10^4
3/16/PM	9,866	6.43×10^4
4/18/AM	9,722	5.86×10^4
4/18/PM	9,703	5.66×10^4
4/19/AM	9,696	6.06×10^4
4/19/PM	9,696	5.73×10^4
4/20/AM	9,696	6.24×10^4
4/20/PM	9,716	6.53×10^4
4/21/AM	9,716	5.91×10^4
4/21/PM	9,716	4.91×10^4
4/23/AM	9,683	5.37×10^4
4/23/PM	9,683	6.63×10^4
4/24/AM	9,683	6.00×10^4
4/24/PM	9,709	6.96×10^4
4/25/AM	9,709	5.61×10^4

(continued)

TABLE B-2. (continued)

Date	F-factor power (Fd)	Calculated EPS inlet flow (DSCFM)
1	59	60
5/7/PM	9,557	3.68×10^4
5/8/AM	9,557	7.43×10^4
5/8/PM	9,566	7.06×10^4
5/9/AM	9,566	5.81×10^4
5/9/PM	9,566	7.35×10^4
5/10/AM	9,557	6.04×10^4
5/10/PM	9,621	6.72×10^4
5/11/AM	9,492	6.36×10^4
5/11/PM	9,492	6.55×10^4
5/14/AM	9,492	5.95×10^4
5/14/PM	9,728	6.10×10^4
5/15/AM	9,728	6.00×10^4
5/15/PM	9,728	6.21×10^4
5/16/AM	9,728	7.25×10^4
5/16/PM	9,728	7.61×10^4
5/17/AM	9,728	6.93×10^4
5/17/PM	9,728	7.02×10^4
5/18/AM	9,728	6.62×10^4
5/18/PM	9,728	6.98×10^4

(continued)

TABLE B-3. FUEL AND ASH DATA

Date 61	Coal type 62	Pellet type 63	Fly ash reinjection 64	ESP collect resistivity (Ω - CM) 65	Grate speed (ft/hr) 66	Rotor speed spreader (rpm) 67
3/5	A	---	on		---	---
3/6	A	---	on		7.8	715
3/7	A	---	on		9.7	670
3/8	A	---	on		12.3	670
3/9	A	---	on		11.0	660
3/12	B	N	on		9.4	770
3/13	B	N	on		12.3	720
3/14	B	N	on		11.8	695
3/15	B	N	on		13.3	795
3/16	B	N	on		14.3	750
4/18	C	T	on	---	12.0	670
4/19	C	T	on	---	11.0	720
4/20	C	T	on	---	14.3	695
4/21	C	T	on	---	12.5	720
4/22	C	T	on	---	---	---
4/23	C	T	on	---	12.0	665
4/24	C	T	off	---	10.2	695
4/25	C	T	off	---	7.8	660
5/7	D	T	on	---	8.1	735
5/8	D	T	on	1.57×10^6	13.6	695
5/9	D	T	off	1.05×10^8	11.2	655
5/10	D	T	on	---	12.0	---
5/11	D	T	on	---	10.2	635
5/14	E	---	on	---	11.0	685
5/15	E	---	on	---	6.0	650
5/16	E	---	on	2.09×10^4	8.9	660
5/17	E	---	on	---	9.1	635
5/18	E	---	off	4.36×10^4	7.8	640

(continued)

TABLE B-3. (continued)

Date	Ash bed depth (in.)	Bottom ash weight measured (lb/hr)	Bottom ash unburnt comb. (%)	Bottom ash size (% <1/4")	Boiler outlet fly ash (lb/hr)	Boiler outlet fly ash size (µm)
61	68	69	70	71	72	73
3/5	---	---	10.22	--	---	---
3/6	---	1,450	5.98	71	---	---
3/7	---	---	10*	--	---	---
3/8	---	2,600	9.63	70	---	---
3/9	---	1,727	9.15	75	---	---
3/12	---	---	5.76	48	---	---
3/13	---	4,140	6.99	43	---	---
3/14	4	3,128	7.01	45	---	---
3/15	3.5	4,390	13.97	44	---	---
3/16	3	3,420	11.85	52	---	---
4/18	2.5	---	10*	--	---	---
4/19	2	---	19.45	80	---	---
4/20	2	---	10.42	89	---	---
4/21	1.5	---	10*	--	---	---
4/22	---	---	---	--	---	---
4/23	1	---	10*	--	---	---
4/24	3.5	---	10.65	70	---	---
4/25	3	---	---	--	---	---
5/7	1.5	---	15.43	--	---	---
5/8	2	---	10.65	76	14,354	---
5/9	---	3,950	9.01	78	9,035	---
5/10	---	---	6.24	70	14,540	393
5/11	---	2,580	1.07	75	10,393	300
5/14	2	---	9.95	72	5,751	279
5/15	2	860	5.18	83	10,623	327
5/16	2.5	---	13.46	78	10,046	362
5/17	1.5	---	11.26	81	10,625	472
5/18	1.5	---	11.87	72	10,638	552

* Assumed

(continued)

TABLE B-3. (continued)

Date	Boiler outlet unburnt comb. (%)	Multiclone particulate (lb/hr)	Multiclone size distribution (% >90μm)	Multiclone unburnt comb. (%)	ESP collect particulate (lb/hr)**
61	74	75	76	77	78
3/5	---		73.6	13.82	---
3/6	---		51.8	15.40	---
3/7	---		55.6	11.79	---
3/8	---		58.9	22.19	855
3/9	---		56.8	13.59	360
3/12	---		63.3	13.60	---
3/13	---		52.0	11.23	---
3/14	---		50.1	7.99	---
3/15	---		45.5	16.75	840
3/16	---		48.0	11.99	96
4/18	---		62.6	12.57	---
4/19	---		65.2	12.79	774
4/20	---		56.7	11.15	729
4/21	---		54.7	16.57	---
4/22	---		---	---	---
4/23	---		55.5	14.95	---
4/24	---	391	52.5	16.54	444
4/25	---	260	43.7	20.30	414
5/7	---		56.6	29.96	---
5/8	---		59.0	10.21	378
5/9	---		38.8	20.75	402
5/10	27.4		57.2	14.39	573
5/11	29.1		50.0	17.27	501
5/14	34.9		61.3	16.61	---
5/15	31.9		66.7	20.96	---
5/16	28.8		60.0	28.45	1,062
5/17	36.2		55.1	13.04	783
5/18	48.4		45.3	35.29	681

** Calculated by difference in Method 5 results of inlet-outlet

(continued)

TABLE B-3. (continued)

Date	ESP size distribution (µm)	ESP unburnt comb. (%)	Coal F-factor (SCF/10^6 Btu)	Coal type	Coal moisture as received (%)
61	79	80	81	82	83
3/5	---	36.5	9,680	A	6.0
3/6	---	25.9	9,741	A	6.2
3/7	---	27.0	9,863	A	8.2
3/8	---	24.9	9,805	A	8.5
3/9	---	24.5	9,831	A	9.9
3/12	---	36.7			---
3/13	---	21.6	9,672	B	4.5
3/14	---	20.65	10,037	B	6.9
3/15	---	19.81	10,023	B	5.5
3/16	---	18.75	9,758	B	7.7
4/18	---	24.36	9,605	C	6.5
4/19	---	24.36	9,720	C	6.9
4/20	---	23.27	9,918	C	5.5
4/21	---	22.11	9,738	C	5.7
4/22	---	---			---
4/23	---	26.99	10,193	C	8.1
4/24	---	22.66	10,483	C	5.5
4/25	---	21.32	9,771	C	5.2
5/7	---	39.03	9,729	D	4.9
5/8	11.43	25.58	9,661	D	7.4
5/9	9.43	20.67	9,832	D	6.5
5/10	---	23.39	9,721	D	4.7
5/11	---	11.08	9,740	D	6.8
5/14	---	30.16			7.8
5/15	---	28.28	9,763	E	5.5
5/16	12.42	39.67	9,633	E	4.0
5/17	---	42.74	9,645	E	5.4
5/18	13.71	33.64	9,825	E	6.1

(continued)

TABLE B-3. (continued)

Date	Coal fixed carbon dry (%)	Coal volatiles dry (%)	Coal ash dry (%)	Coal H_2 dry (%)	Coal carbon dry (%)	Coal N_2 dry (%)	Coal S dry (%)
61	84	85	86	87	88	89	90
3/5	48.78	37.08	14.14	4.71	70.06	1.01	4.21
3/6	48.26	34.75	16.99	4.52	67.54	1.07	3.74
3/7	49.11	36.11	14.78	4.82	69.69	1.13	3.97
3/8	47.79	36.85	16.34	4.87	67.23	1.09	3.36
3/9	48.80	35.52	15.68	4.89	67.95	1.02	5.49
3/12	---	---	---	---	---	---	---
3/13	46.18	35.40	18.42	4.50	63.79	1.00	7.56
3/14	47.53	34.27	18.20	4.45	65.66	1.03	7.62
3/15	45.40	34.12	20.48	4.87	62.92	0.96	7.37
3/16	47.49	36.67	15.84	4.39	68.50	1.09	4.57
4/18	53.66	34.29	12.05	4.90	71.31	1.29	1.64
4/19	51.98	34.90	13.11	4.94	70.87	1.22	2.26
4/20	50.32	32.99	16.69	4.65	68.92	1.18	2.89
4/21	53.10	36.00	10.61	5.09	73.51	1.18	1.82
4/22	---	---	---	---	---	---	---
4/23	52.81	35.42	11.77	5.58	72.51	1.15	2.82
4/24	54.17	35.85	9.97	5.08	74.50	1.27	1.90
4/25	49.84	34.19	15.96	4.72	67.65	1.19	2.10
5/7	54.35	35.67	9.97	5.03	72.28	1.30	2.01
5/8	53.62	36.57	9.81	4.80	72.83	1.25	2.31
5/9	56.34	36.41	7.25	4.84	75.09	1.39	1.01
5/10	54.89	35.67	9.44	4.67	72.11	1.21	1.79
5/11	53.63	35.43	10.94	4.77	73.27	1.20	1.53
5/14	---	---	---	---	---	---	---
5/15	54.57	34.30	11.13	4.88	73.28	1.25	2.97
5/16	53.57	35.80	10.63	4.77	74.15	1.19	1.83
5/17	55.06	35.35	9.59	4.60	76.18	1.26	1.50
5/18	55.66	35.43	8.91	5.27	75.67	1.29	2.07

(continued)

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TABLE B-3. (continued)

Date	Coal Cl dry (%)	Coal O_2 dry (%)	Coal density as received (lb/ft^3)	Coal fines <3/8" as received (%)	Coal HHV dry (Btu/lb)	Initial deformation temperature (°F)
61	91	92	93	94	95	96
3/5	0.12	5.75	52.20	68	12,691	1,920
3/6	0.14	6.00	51.47	67	12,112	1,980
3/7	0.15	5.46	53.40	84	12,436	1,960
3/8	0.13	6.98	49.99	84	12,035	1,970
3/9	0.14	4.83	50.65	82	12,347	1,930
3/12	---	---	53.39	--	---	---
3/13	0.14	4.59	52.82	30	11,892	1,920
3/14	0.13	2.91	54.04	56	11,809	1,940
3/15	0.13	3.27	54.15	44	11,515	1,940
3/16	0.14	5.47	54.21	39	12,271	1,980
4/18	0.16	8.65	52.53	50	12,766	2,340
4/19	0.14	7.46	50.55	57	12,651	2,040
4/20	0.11	5.56	52.64	59	12,125	2,040
4/21	0.17	7.32	49.67	39	13,075	2,360
4/22	---	---	---	--	---	---
4/23	0.16	6.01	50.49	48	12,616	2,000
4/24	0.21	6.92	50.71	58	12,310	2,140
4/25	0.14	8.24	50.17	47	11,959	2,400
5/7	0.13	9.28	53.97	36	12,793	2,060
5/8	0.14	8.86	54.30	62	12,926	2,140
5/9	0.12	10.30	52.97	41	12,926	2,460
5/10	0.08	10.70	52.39	39	12,570	2,060
5/11	0.15	8.14	52.06	64	12,868	2,120
5/14	---	---	53.79	--	---	---
5/15	0.16	6.33	53.71	65	13,046	2,020
5/16	0.16	7.27	52.06	63	13,209	2,180
5/17	0.16	6.71	52.80	58	12,465	2,500
5/18	0.18	6.62	---	62	13,404	2,100

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TABLE B-3. (continued)

Date 61	Coal softening temp. (°F) 97	Coal hemispherical temperature (°F) 98	Coal fluid temp. (°F) 99	Coal ash free moisture free (Btu/lb) 100	Coal A-R (HHV) 100A
3/5	2000	2160	2260	14,781	11,929
3/6	2080	2220	2340	14,591	11,361
3/7	2060	2200	2340	14,593	11,416
3/8	2030	2160	2330	14,386	11,012
3/9	2000	2080	2300	14,643	11,124
3/12	---	---	---	---	---
3/13	1980	2060	2180	14,577	11,357
3/14	1980	2080	2300	14,436	10,994
3/15	1980	2080	2180	14,481	10,882
3/16	2040	2150	2250	14,581	11,387
4/18	2420	2460	2500	14,515	11,936
4/19	2140	2340	2420	14,560	11,778
4/20	2180	2340	2380	14,554	11,458
4/21	2400	2440	2560	14,627	12,329
4/22	---	---	---	---	---
4/23	2100	2160	2420	14,299	11,594
4/24	2400	2440	2580	13,673	11,633
4/25	2460	2520	2580	14,230	11,337
5/7	2140	2180	2500	14,210	12,166
5/8	2440	2480	2580	14,332	11,969
5/9	2540	2600	2720	13,936	12,086
5/10	2160	2320	2480	13,880	11,979
5/11	2360	2420	2520	14,449	11,992
5/14	---	---	---	---	---
5/15	2080	2180	2300	14,680	12,328
5/16	2400	2440	2500	14,780	12,681
5/17	2580	2600	2620	14,893	12,738
5/18	2480	2520	2560	14,715	12,586

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TABLE B-3. (continued)

Date	Pellet F-factor ($SCF/10^6$ Btu)	Pellet type	Pellet moisture as received (%)	Pellet fixed carbon dry (%)	Pellet volatiles dry (%)
61	101	102	103	104	105
3/5					
3/6					
3/7					
3/8					
3/9					
3/12					
3/13	11,310	N	18.0	12.03	54.60
3/14	9,528	N	29.5	13.06	53.98
3/15	9,572	N	18.5	13.15	58.68
3/16	9,552	N	23.3	20.72	50.79
4/18	9,326	T	30.4	15.67	68.83
4/19	9,149	T	31.4	12.26	76.44
4/20	9,471	T	33.4	15.06	72.49
4/21	9,603	T	30.4	12.70	72.06
4/22	9,024	T	---	---	---
4/23	9,024	T	28.2	11.79	75.52
4/24	9,454	T	23.7	12.53	72.87
4/25	9,201	T	24.8	13.92	67.57
5/7	9,307	T	21.4	12.82	72.29
5/8	9,238	T	16.8	12.78	74.10
5/9	9,250	T	17.6	12.93	72.80
5/10	9,321	T	14.0	11.54	71.72
5/11	9,075	T	14.5	13.72	74.54
5/14					
5/15					
5/16					
5/17					
5/18					
Average properties					
Coal A			---	48.55	36.06
Coal B			---	46.65	35.11
Coal C			---	52.27	34.81
Coal D			---	54.57	35.95
Coal E			---	54.72	35.22
Pellet N			---	14.74	54.51
Pellet T			---	13.14	72.60

(continued)

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TABLE B-3. (continued)

Date 61	Pellet ash dry (%) 106	Pellet H_2 dry (%) 107	Pellet carbon dry (%) 108	Pellet N_2 dry (%) 109	Pellet S dry (%) 110	Pellet chlorine dry (%) 111
3/5						
3/6						
3/7						
3/8						
3/9						
3/12						
3/13	33.37	5.58	42.66	0.65	0.41	0.31
3/14	32.96	4.25	37.48	0.56	0.58	0.28
3/15	28.17	4.77	40.88	0.65	0.21	0.36
3/16	28.49	3.90	41.45	0.49	0.52	0.31
4/18	15.51	5.58	47.84	0.50	0.44	0.44
4/19	11.30	6.63	47.88	0.38	0.32	0.32
4/20	12.44	6.06	47.31	0.39	0.25	0.41
4/21	15.24	6.50	45.26	0.40	0.13	0.42
4/22	---	---	---	---	---	---
4/23	12.70	6.29	46.25	0.31	0.27	0.41
4/24	14.61	5.84	46.37	0.39	0.31	0.27
4/25	13.52	5.87	43.51	0.38	0.20	0.43
5/7	14.89	5.91	44.49	0.35	0.19	0.30
5/8	13.12	6.33	46.18	0.33	0.09	0.48
5/9	14.27	6.49	44.44	0.34	0.15	0.44
5/10	16.74	5.88	43.88	0.39	0.30	0.35
5/11	11.75	6.15	44.90	0.32	0.17	0.35
5/14						
5/15						
5/16						
5/17						
5/18						
			Average properties			
Coal A	15.59	4.76	68.49	1.06	4.15	0.14
Coal B	18.24	4.55	65.22	1.02	6.78	0.14
Coal C	12.88	4.99	71.32	1.21	2.20	0.16
Coal D	9.48	4.82	73.12	1.27	1.73	0.12
Coal E	10.06	4.88	74.82	1.25	2.09	0.16
Pellet N	30.75	4.63	40.62	0.59	0.43	0.31
Pellet T	13.84	6.13	45.69	0.37	0.23	0.38

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TABLE B-3. (continued)

Date	Pellet O_2 dry (%)	Pellet as received bulk density (lb/ft^3)	Pellet fines <3/8" as received (%)	Pellet HHV dry (Btu/lb)	Pellet initial deformation temp. (°F)
61	112	113	114	115	116
3/5					
3/6					
3/7					
3/8					
3/9					
3/12		31.03			
3/13	17.02	33.53	54.3	6,755	1,940
3/14	23.89	35.00	52.2	6,398	1,960
3/15	24.96	34.05	39.1	7,021	1,940
3/16	24.84	34.62	41.0	6,845	1,970
4/18	29.68	34.49	10.1	8,417	2,040
4/19	33.42	36.14	20.2	8,773	2,020
4/20	33.14	37.29	33.3	8,191	2,080
4/21	32.05	32.59	21.7	7,950	1,960
4/22	---	---	---	---	---
4/23	33.77	32.73	19.5	8,470	2,030
4/24	32.21	34.10	41.7	8,025	1,980
4/25	31.09	31.35	47.9	7,830	1,970
5/7	33.87	30.36	26.7	7,778	1,940
5/8	33.47	30.31	23.7	8,281	1,980
5/9	33.87	29.37	34.3	8,024	1,900
5/10	32.46	31.96	25.1	7,732	1,960
5/11	36.36	30.61	30.3	8,006	1,920
5/14					
5/15					
5/16					
5/17					
5/18					
			Average properties		
Coal A	5.80	51.54	---	12,324	
Coal B	4.06	53.81	---	11,872	
Coal C	7.16	50.96	---	12,500	
Coal D	9.46	53.14	---	12,817	
Coal E	6.73	53.09	---	13,281	
Pellet N	22.68	33.65	---	6,755	
Pellet T	32.95	32.61	---	8,123	

(continued)

TABLE B-3. (continued)

Date	Pellet Softening temp. (°F)	Pellet hemispherical temperature (°F)	Pellet fluid temp. (°F)	Pellet ash free moisture free (Btu/lb)	Pellet A-R (HHV)
61	117	118	119	120	120A
3/5					
3/6					
3/7					
3/8					
3/9					
3/12					
3/13	2000	2100	2420	10,138	5,539
3/14	2020	2100	2360	9,455	4,511
3/15	2000	2100	2340	9,774	5,722
3/16	2040	2130	2360	9,578	5,250
4/18	2070	2110	2280	9,962	5,858
4/19	2060	2110	2260	9,891	6,018
4/20	2130	2180	2360	9,355	5,455
4/21	2040	2140	2300	9,379	5,533
4/22	---	---	---	---	---
4/23	2090	2160	2360	9,702	6,081
4/24	2050	2120	2350	9,398	5,320
4/25	2070	2160	2430	9,054	5,888
5/7	2020	2100	2250	9,139	6,114
5/8	2080	2200	2500	9,532	6,890
5/9	1960	2040	2360	9,360	6,612
5/10	2020	2080	2440	9,287	6,650
5/11	1980	2040	2400	9,072	6,845
5/14					
5/15					
5/16					
5/17					
5/18					

	Ash $\frac{\text{lb}}{10^6 \text{ Btu}}$	S $\frac{\text{lb}}{10^6 \text{ Btu}}$	N $\frac{\text{lb}}{10^6 \text{ Btu}}$
Coal A	12.65	3.37	.86
Coal B	15.36	5.71	.86
Coal C	10.30	1.76	.97
Coal D	7.39	1.35	.99
Coal E	7.57	1.57	.94
Pellet N	45.52	0.64	.87
Pellet T	17.03	0.28	.45

(continued)

TABLE B-3. (continued)

Date	Time Δt (hr)	Coal input dry basis (lb/hr)	Pellet input dry basis (lb/hr)	Calculated density (lb/ft^3)	Measured density (lb/ft^3)	Calculated fixed carbon
121	122	123	124	125	126	127
3/5	16.25	6618	*	52.20	52.21	*
3/6	24.50	11105	*	51.47	51.48	*
3/7	24.00	15694	*	53.40	53.40	*
3/8	24.33	19171	*	49.99	49.99	*
3/9	13.20	18408	*	50.65	50.65	*
3/12	21.81	16628	6002	42.28	40.21	38.19
3/13	27.18	11215	7600	42.13	41.62	33.76
3/14	25.00	10763	6236	43.73	41.47	34.96
3/15	20.00	14691	8607	43.71	42.01	34.86
3/16	14.00	13672	7967	43.96	41.68	34.90
4/18	23.15	10443	6896	41.66	44.77	36.71
4/19	27.00	11528	8598	42.10	41.58	35.55
4/20	20.83	8267	5584	43.81	38.89	36.49
4/21	25.00	6117	4515	42.11	40.92	35.65
4/23	26.53	8053	6711	39.45	40.21	34.48
4/24	24.00	12339	8772	40.73	39.05	36.01
4/25	–	12378	8772	–	36.64	36.04
5/7	22.66	5421	4866	38.42	40.27	34.97
5/8	20.92	9333	8073	39.11	33.44	35.35
5/9	22.68	11115	9741	37.74	37.29	35.22
5/10	21.75	10942	10211	40.80	39.60	34.57
5/11	11.22	9415	16103	35.75	37.79	28.43
5/14	20.25	7454	*	–	53.79	*
5/15	24.65	29361	*	53.71	53.71	*
5/16	23.25	16669	*	52.06	52.06	*
5/17	23.83	18110	*	52.80	52.80	*
5/18			*	–		*

(continued)

TABLE B-3. (continued)

Date	Lab analysis fixed carbon (%)	Calculated volatiles	Lab analysis volatiles (%)	Calculated ash	Lab analysis ash (%)
121	128	129	130	131	132
3/5	48.78	*	37.08	*	14.14
3/6	48.26	*	34.75	*	16.99
3/7	49.11	*	36.11	*	14.78
3/8	47.79	*	35.87	*	16.34
3/9	48.80	*	35.52	*	15.68
3/12	42.67	40.26	40.70	21.56	16.63
3/13	38.99	42.95	40.06	23.29	20.95
3/14	38.64	42.23	42.36	22.83	19.00
3/15	40.34	42.28	40.66	22.86	19.00
3/16	40.69	42.25	38.65	22.85	20.66
4/18	47.28	49.84	42.08	13.26	10.64
4/19	37.67	50.95	51.50	13.29	10.83
4/20	41.53	50.04	47.26	13.27	11.21
4/21	42.08	50.86	346.66	13.29	11.26
4/23	37.08	51.99	50.24	13.32	12.68
4/24	45.75	50.51	43.92	13.28	10.33
4/25	27.54	50.48	60.65	13.28	11.81
5/7	41.60	53.29	48.67	11.54	9.73
5/8	29.00	52.95	58.12	11.50	12.88
5/9	28.82	53.07	57.57	11.52	13.61
5/10	29.01	66.74	58.86	11.58	12.13
5/11	28.77	59.08	58.03	12.23	13.20
5/14	-	*	-	*	-
5/15	54.57	*	37.30	*	11.13
5/16	53.57	*	35.80	*	10.63
5/17	55.06	*	35.35	*	9.59
5/18	55.66	*	34.43	*	8.91

(continued)

TABLE B-3. (continued)

Date	Calculated carbon	Lab analysis carbon (%)	Calculated hydrogen	Lab analysis hydrogen (%)	Calculated heating value
121	133	134	135	136	137
3/5	*	70.06	*	4.71	*
3/6	*	67.54	*	4.52	*
3/7	*	69.69	*	4.82	*
3/8	*	67.23	*	4.87	*
3/9	*	67.95	*	4.89	*
3/12	58.70	63.02	4.57	4.97	10515
3/13	55.28	59.79	4.58	4.86	9805
3/14	56.20	59.84	4.58	5.20	9995
3/15	56.13	58.60	4.58	5.28	9982
3/16	56.16	59.49	4.58	5.05	9988
4/18	61.13	68.07	5.44	5.19	10759
4/19	60.37	62.26	5.48	5.76	10630
4/20	60.99	65.18	5.45	5.31	10735
4/21	60.44	65.72	5.47	5.49	10641
4/23	59.67	61.42	5.51	5.70	10510
4/24	60.67	68.24	5.46	5.11	10681
4/25	60.69	56.33	5.46	6.01	10685
5/7	60.14	63.27	5.44	5.36	10597
5/8	60.40	56.55	5.43	5.62	10640
5/9	60.31	56.26	5.43	5.50	10625
5/10	59.88	54.89	5.45	5.51	10551
5/11	55.81	55.71	5.65	5.75	9855
5/14	*	-	*	-	*
5/15	*	73.28	*	4.88	*
5/16	*	74.15	*	4.77	*
5/17	*	76.18	*	4.60	*
5/18	75.67	*	5.27	*	*

(continued)

TABLE B-3. (continued)

Date	Lab analysis heating value (Btu/lb)	Calculated sulfur (%)	Measured sulfur (%)
121	138	139	140
3/5	12691	*	4.21
3/6	12112	*	3.74
3/7	12436	*	3.97
3/8	12035	*	3.36
3/9	12347	*	5.49
3/12	11485	5.10	2.44
3/13	10750	4.22	3.47
3/14	10772	4.45	2.56
3/15	10733	4.43	2.00
3/16	10884	4.44	2.38
4/18	12018	1.42	1.21
4/19	11334	1.36	1.23
4/20	11746	1.41	1.60
4/21	11658	1.36	1.38
4/23	11036	1.30	1.96
4/24	12136	1.38	1.45
4/25	9890	1.38	0.70
5/7	11139	1.02	1.05
5/8	10067	1.03	0.66
5/9	9945	1.03	0.55
5/10	9792	1.01	0.60
5/11	9723	0.78	0.94
5/14	-	*	-
5/15	13046	*	2.97
5/16	13209	*	1.83
5/17	13465	*	1.50
5/18	13404	*	2.07

(continued)

TABLE B-3. (continued)

Date	Boiler load (10^3-lb/hr)	Frequency of load swings (hr^{-1})	Amplitude of load swings (10^3 lb/hr)	Blend ratio by weight (dRDF/coal)	Fly ash reinj. (on/off)
121	141	142	143	144	145
3/5	68.8	2.1	10	0	on
3/6	65.5	1.9	10	0	on
3/7	119.9	3.2	15	0	on
3/8	143.1	2.3	10	0	on
3/9	145.2	1.8	10	0	on
3/12	65.1	1.9	15	0.434	on
3/13	109.6	3.2	20	0.789	on
3/14	110.8	3.0	13	0.765	on
3/15	123.2	3.3	22	0.679	on
3/16	125.6	3.1	20	0.701	on
4/18	119.6	3.9	15	0.922	on
4/19	128.3	3.1	20	1.012	on
4/20	133.7	5.9	23	0.959	on
4/21	56.7	1.4	10	0.522	on
4/22	---	1.7	8	---	on
4/23	112.2	4.9	20	1.065	on
4/24	137.5	5.1	15	1.013	off
4/25	134.9	4.0	15	1.013	off
5/7	60.0	3.3	15	1.086	on
5/8	149.7	6.0	30	0.963	on
5/9	144.1	6.1	25	1.015	off
5/10	148.1	6.0	15	0.782	on
5/11	145.4	5.2	15	1.864	on
5/14	88.7	2.9	15	0	on
5/15	106.5	2.7	10	0	on
5/16	137.8	4.9	10	0	on
5/17	135.5	3.5	10	0	on
5/18	139.1	3.9	12	0	off

(continued)

TABLE B-3. (continued)

Date	Boiler outlet CO_2 (%)	Boiler outlet O_2 (%)	Excess air boiler outlet (%)	Boiler outlet CO (ppm)	Screen tubes CO_2 (Δ%)	Unburnt HC (boiler outlet (ppm)	Opacity econ. outlet (%)
121	146	147	148	149	150	151	152
3/5	7.3	10.7	95	86.4	---	<10	10.6
3/6	6.1	11.4	106	98.2	---	<10	16.8
3/7	8.0	10.0	86	---	---	---	13.7
3/8	10.1	6.6	42	92.4	---	<10	24.1
3/9	9.5	8.6	64	123.9	---	<10	20.2
3/12	7.7	10.0	83	133.2	---	---	9.7
3/13	10.6	7.1	47	91.8	---	---	7.9
3/14	8.4	10.3	90	115.6	---	---	10.6
3/15	8.5	10.1	86	221.1	---	---	18.1
3/16	10.8	7.6	53	128.2	---	---	19.5
4/18	11.6	7.6	54	146.9	1.00	---	27.6
4/19	10.7	7.8	55	142.8	0.95	---	28.7
4/20	10.6	7.7	54	126.9	2.37	<10	33.5
4/21	7.1	14.4	216	243.8	---	---	46.2
4/22	---	---	---	---	---	---	---
4/23	7.5	12.4	136	254.5	1.55	---	49.1
4/24	9.2	8.8	68	---	0.67	---	13.9
4/25	---	9.4	75	156.2	0.50	---	35.0
5/7	7.2	12.4	135	211.1	0.30	---	12.4
5/8	10.5	8.9	70	234.4	0.12	---	29.4
5/9	11.4	7.6	54	132.8	0.33	---	24.4
5/10	9.5	9.9	84	114.3	0.36	---	23.8
5/11	10.6	7.1	47	89.4	0.76	---	19.0
5/14	8.5	11.2	108	164.1	1.21	---	16.6
5/15	10.8	7.8	55	69.5	3.12	---	27.4
5/16	10.2	8.6	65	89.2	2.62	---	31.3
5/17	11.5	7.2	49	100.0	2.45	---	26.2
5/18	10.0	8.5	64	94.3	1.26	---	22.7

(continued)

TABLE B-3. (continued)

Date	Steam pressure (psig)	Steam temp. (°F)	Flame temp. (°F)	Super heater gas temp. (°F)	Convective section gas temp. (°F)	Boiler outlet gas temp. (°F)
121	153	154	155	156	157	158
3/5	615	795	2,451	1,100	685	600
3/6	620	790	2,349	1,055	665	590
3/7	620	825	2,675	1,155	780	655
3/8	620	840	2,677	1,215	830	700
3/9	620	840	2,688	1,280	865	695
3/12	620	775	2,408	1,010	655	580
3/13	620	825	2,563	1,125	760	640
3/14	620	840	2,572	1,130	795	640
3/15	620	840	2,511	1,130	795	645
3/16	620	835	2,518	1,175	800	660
4/18	625	830	2,375	1,210	780	650
4/19	625	850	2,375	1,160	840	680
4/20	625	845	2,325	1,240	830	675
4/21	615	785	2,402	930	630	590
4/22	---	---	2,040	---	---	---
4/23	610	830	1,866	1,190	785	650
4/24	615	860	1,950	1,210	830	675
4/25	620	855	2,600	1,240	815	665
5/7	615	815	---	935	660	585
5/8	615	860	---	1,220	875	700
5/9	615	860	---	1,280	880	690
5/10	615	860	---	1,215	855	700
5/11	615	850	---	1,265	850	690
5/14	600	810	1,528	1,090	790	630
5/15	600	825	1,492	1,250	850	660
5/16	610	850	1,573	1,245	920	715
5/17	610	845	1,581	1,255	890	700
5/18	610	850	1,528	1,280	835	690

(continued)

TABLE B-3. (continued)

Date	Economizer outlet gas temp. (°F)	ESP inlet gas temp. (°F)	CO_2 boiler outlet (%)	CO_2 ESP outlet (%)	O_2 boiler outlet (%)	O_2 ESP outlet (%)	CO boiler outlet (ppm)
121	159	160	161	162	163	164	165
3/5	400	372	7.3	6.2	10.7	12.8	86.4
3/6	395	361	6.1	5.1	11.4	13.5	98.2
3/7	410	390	---	7.9	---	11.4	---
3/8	435	408	10.1	8.6	6.6	8.7	92.4
3/9	420	410	9.4	8.9	8.6	9.4	123.9
3/12	375	---	7.7	---	10.0	---	133.2
3/13	420	387	10.6	8.2	7.0	9.8	91.8
3/14	430	391	8.4	8.0	10.3	10.7	115.6
3/15	430	378	8.5	---	10.1	---	221.1
3/16	435	402	10.8	7.8	7.6	10.9	128.2
4/18	415	393	11.6	9.0	7.6	10.5	146.9
4/19	440	402	10.7	8.9	7.8	10.4	142.8
4/20	440	392	10.6	8.9	7.7	10.5	126.9
4/21	400	355	7.1	6.2	14.4	15.7	243.8
4/22	---	---	---	---	---	---	---
4/23	420	372	7.5	9.3	12.4	10.4	254.5
4/24	440	392	---	9.5	---	10.5	---
4/25	430	374	---	---	9.4	11.1	156.2
5/7	360	359	7.2	6.7	12.4	12.6	211.1
5/8	440	387	10.5	9.2	8.9	10.5	234.4
5/9	440	380	11.4	9.4	7.6	10.2	132.8
5/10	440	393	9.5	9.2	9.9	9.6	114.3
5/11	440	399	10.6	8.9	7.1	10.0	89.4
5/14	425	384	8.5	5.6	11.2	15.1	164.1
5/15	435	403	10.8	7.7	7.8	11.7	69.5
5/16	455	402	10.2	8.4	8.6	11.1	89.2
5/17	445	400	11.5	8.8	7.2	10.5	100.0
5/18	435	397	10.2	9.3	8.5	10.4	94.3

(continued)

TABLE B-3. (continued)

Date	CO ESP outlet (ppm)	NO_x boiler outlet (ppm)	NO_x ESP outlet (ppm)	SO_x boiler outlet (ppm)	SO_x ESP boiler (ppm)	Molecular weight boiler outlet gas (lb/mole)
121	166	167	168	169	170	171
3/5	90.5	248.7	201.5	219.8	179.58	29.25
3/6	117.7	---	---	2,030.0	1,766.0	29.13
3/7	103.1	---	---	---	2,184.0	29.40
3/8	131.7	---	---	1,321.0	1,871.0	29.04
3/9	113.5	---	---	2,687.0	1,323.0	29.51
3/12	---	---	---	1,486.0	---	---
3/13	162.9	386.4	232.4	1,700.0	1,200.0	29.31
3/14	99.5	---	---	1,618.2	1,179.1	29.31
3/15	---	---	---	1,361.4	---	29.31
3/16	245.8	---	---	1,452.3	1,089.0	29.31
4/18	155.8	320.8	246.3	733.5	599.4	29.29
4/19	129.1	---	---	725.3	580.2	29.13
4/20	110.4	---	---	755.3	577.4	29.12
4/21	200	---	---	721.9	649.6	29.27
4/22	---	---	---	---	---	---
4/23	106.4	---	---	405.2	553.2	28.90
4/24	125.1	---	---	---	---	29.23
4/25	492.7	233.3	277.6	711.5	483.0	29.02
5/7	76.6	231.9	180.1	460.4	329.9	29.03
5/8	257.1	---	---	579.1	609.7	29.21
5/9	140.3	306.3	220.9	593.5	430.5	29.31
5/10	100.4	523.3	263.1	432.5	452.6	29.00
5/11	98.0	---	---	510.6	297.2	29.02
5/14	195.0	223.8	173.0	356.3	338.5	29.31
5/15	70.4	---	---	1,111.0	652.9	29.52
5/16	86.0	207.4	168.4	478.8	475.8	29.55
5/17	95.7	4.5	3.9	375.0	394.6	29.61
5/18	92.3	316.6	270.0	628.8	454.2	29.36

(continued)

TABLE B-3. (continued)

Date 121	Economizer inlet gas temp. (°F) 172	Boiler outlet gas flow rate (EST.) (lb/hr) 173	Economizer inlet water temp. (°F) 174	Economizer outlet water temp. (°F) 175	Feedwater enthalpy (Btu/lb) 176
3/5	597	229,000	259	378	227.7
3/6	592	239,000	261	399	229.8
3/7	657	317,000	251	384	219.6
3/8	698	371,000	249	385	217.6
3/9	697	365,000	251	420	219.6
3/12	581	---	260	380	228.8
3/13	638	306,000	258	383	226.7
3/14	642	322,000	255	384	223.7
3/15	648	367,000	254	382	222.6
3/16	662	369,000	254	383	222.6
4/18	653	314,000	260	380	228.8
4/19	681	355,000	251	390	219.6
4/20	676	298,000	254	383	222.6
4/21	587	232,000	255	384	223.7
4/22	---	---	---	---	---
4/23	650	322,000	255	385	223.7
4/24	676	349,000	251	376	219.6
4/25	664	342,000	250	377	218.6
5/7	586	216,000	206	355	174.1
5/8	698	389,000	256	380	224.7
5/9	692	384,000	248	380	216.6
5/10	700	364,000	250	385	218.6
5/11	690	355,000	251	383	219.6
5/14	629	333,000	262	398	230.8
5/15	662	353,000	256	389	224.7
5/16	711	432,000	251	390	219.6
5/17	700	382,000	254	387	222.7
5/18	688	368,000	252	383	220.6

(continued)

TABLE B-3. (continued)

Date	Steam enthalpy (Btu/lb)	Screen tubes gas temp. (°F)	Wind box pressure (in H_2O)	Steam enthalpy gain (Btu/lb)
121	177	178	179	180
3/5	1,404	1,094	0.16	1,176
3/6	1,401	1,056	0.36	1,171
3/7	1,420	1,155	0.70	1,200
3/8	1,428	1,217	0.98	1,210
3/9	1,428	1,281	1.00	1,208
3/12	1,392	1,012	0.08	1,163
3/13	1,420	1,126	0.59	1,193
3/14	1,428	1,133	0.73	1,204
3/15	1,428	1,131	0.78	1,205
3/16	1,425	1,175	0.75	1,202
4/18	1,423	1,207	0.55	1,194
4/19	1,434	1,239	0.87	1,214
4/20	1,431	1,241	0.73	1,208
4/21	1,398	932	0.23	1,174
4/22	---	---	---	---
4/23	1,424	1,202	0.70	1,200
4/24	1,440	1,208	0.83	1,220
4/25	1,436	1,241	0.87	1,217
5/7	1,415	935	0.41	1,241
5/8	1,440	1,218	1.10	1,215
5/9	1,440	1,278	1.11	1,223
5/10	1,440	1,240	0.98	1,221
5/11	1,434	1,265	0.98	1,214
5/14	1,413	1,088	0.79	1,182
5/15	1,421	1,251	0.80	1,196
5/16	1,435	1,247	1.19	1,215
5/17	1,432	1,257	1.02	1,209
5/18	1,435	1,280	0.92	1,214

(continued)

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TABLE B-3. (continued)

Date	Initial deformation temp. (°F)	Softening temp. (°F)	Hemispherical temp. (°F)	Fluid temp. (°F)
181	182	183	184	185
3/5				
3/6				
3/7				
3/8				
3/9				
3/12	2,000	2,080	2,140	2,360
3/13	1,960	2,020	2,080	2,280
3/14	1,940	1,980	2,070	2,250
3/15	1,940	1,980	2,070	2,300
3/16	1,980	2,030	2,100	2,300
4/18	2,160	2,280	2,340	2,420
4/19	2,160	2,240	2,320	2,400
4/20	2,040	2,180	2,280	2,340
4/21	2,120	2,230	2,300	2,360
4/22	---	---	---	---
4/23	2,060	2,200	2,300	2,370
4/24	2,140	2,320	2,380	2,460
4/25	2,200	2,300	2,360	2,520
5/7	2,180	2,240	2,320	2,500
5/8	2,200	2,280	2,360	2,560
5/9	2,120	2,180	2,260	2,420
5/10	2,040	2,160	2,240	2,360
5/11	2,060	2,160	2,240	2,380
5/14				
5/15				
5/16				
5/17				
5/18				

(continued)

TABLE B-3. (continued)

Sample type	Date	SiO_2 (%)	(Fe_2O_3)	AL_2O_3	T_1O_2	CaO	MgO
187	188	189	190	191	192	193	194
Blend	3/15	40.4	20.3	14.9	1.60	5.05	1.06
Blend	5/8	47.7	9.53	18.1	2.25	5.56	1.37
Coal	5/16	41.4	17.9	24.4	1.38	3.32	1.47
B-Ash	3/15	49.8	21.5	12.0	1.36	5.00	1.04
B-Ash	5/8	44.4	10.4	17.1	1.76	10.1	3.76
B-Ash	5/16	34.3	11.5	14.2	1.23	17.4	9.89
ESP-Ash	3/15	38.4	21.4	16.6	1.95	4.23	1.05
ESP-Ash	5/8	42.6	14.2	21.1	1.59	3.56	0.84
ESP-Ash	5/16	43.9	14.8	24.7	1.17	3.07	0.75
Mult.	3/15	43.8	20.9	15.8	1.26	5.27	1.13
Mult.	5/8	43.0	19.4	24.1	0.87	2.70	0.78
Mult.	5/16	46.2	16.7	19.5	1.78	4.73	1.28
B.O.Ash	5/8	47.3	14.5	18.0	1.06	5.20	1.85
B.O.Ash	5/16	44.2	15.1	22.7	0.88	4.21	1.85

(continued)

TABLE B-3. (continued)

Sample type	Date	P_2O_5	SO_3	Na_2O	K_2O	CaO + MgO	$\frac{CaO + MgO}{Fe_2O_3}$
187	188	195	196	197	198	199	200
Blend	3/15	0.62	6.90	2.58	0.95	6.11	0.30
Blend	5/8	0.03	5.30	2.66	0.95	6.93	0.73
Coal	5/16	0.46	2.13	0.78	0.95	4.79	0.27
B-Ash	3/15	0.09	2.78	2.74	0.88	6.04	0.31
B-Ash	5/8	0.40	2.28	1.80	0.96	13.86	1.33
B-Ash	5/16	0.15	5.33	0.80	0.90	27.29	2.37
ESP-Ash	3/15	0.95	6.05	2.90	1.06	5.28	0.25
ESP-Ash	5/8	1.19	4.70	2.65	1.07	4.40	0.31
ESP-Ash	5/16	0.58	1.83	0.91	0.90	3.82	0.26
Mult.	3/15	0.73	1.38	3.00	0.99	6.40	0.31
Mult.	5/8	0.32	0.60	0.96	0.98	3.48	0.81
Mult.	5/16	0.68	0.93	2.59	1.01	6.01	0.36
B.O.Ash	5/8	0.47	1.88	1.93	0.99	7.05	0.49
B.O.Ash	5/16	0.42	1.60	0.89	0.96	6.06	0.40

(continued)

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TABLE 8-4. BOILER PERFORMANCE DATA
(The following efficiency data is on a bunker fill time basis)

Date mo/day/no.	Time	Coal input as received (lb/hr)	Pellet input as received (lb/hr)	Coal moisture (%)	Pellet moisture (%)	Coal input dry basis (lb/hr)
201	202	203	204	205	206	207
3/5/1	1615	7,040	*	6.0	*	6,618
3/6/1	0830	10,395	*	6.2	*	9,751
3/6/2	1230	13,282	*	6.2	*	12,459
3/7/1	0900	16,325	*	8.2	*	14,986
3/7/2	1305	17,867	*	8.2	*	16,402
3/8/1	0855	21,382	*	8.5	*	19,565
3/8/2	1335	20,521	*	8.5	*	18,777
3/9/1	0920	20,394	*	9.9	*	18,375
3/9/2	1338	20,467	*	9.9	*	18,441
3/12/1	1100	17,503	7,597	5.0	20.0	16,628
3/12/2	1700	6,866	6,394	5.0	20.0	6,522
3/13/1	0915	11,743	9,268	4.5	18.0	11,215
3/14/1	1230	11,561	8,845	6.9	29.5	10,763
3/15/1	1300	15,546	10,561	5.5	18.5	14,691
3/16/1	0900	14,813	10,387	7.7	23.3	13,672
4/18/1	0910	11,169	9,908	6.5	30.4	10,443
4/18/2	1303	12,203	13,382	6.5	30.4	11,410
4/19/1	0827	12,382	12,534	6.9	31.4	11,528
4/20/1	1126	8,748	8,385	5.5	33.4	8,267
4/21/1	0800	12,4[illegible]	6,487	5.7	30.4	6,117
4/23/1	0927	8,763	9,347	8.1	28.2	8,053
4/23/2	1345	12,483	13,284	8.1	28.2	11,472
4/24/1	1155	13,057	13,231	5.5	33.7	12,339
5/7/1	1430	5,700	6,191	4.9	21.4	5,421
5/8/1	1310	10,079	9,706	7.4	16.8	9,333
5/9/1	1005	11,888	11,822	6.5	17.6	11,115
5/9/2	1516	6,350	6,586	6.5	17.6	5,937
5/10/1	0845	11,482	11,873	4.7	14.0	10,942
5/10/2	1300	10,003	5,306	4.7	14.0	9,533
5/11/1	0900	11,016	20,590	6.8	14.5	10,267
5/11/2	1000	9,188	17,078	6.8	14.5	8,563
5/14/1	1305	8,085	*	7.8	*	7,454
5/15/1	0920	10,634	*	5.5	*	10,049
5/16/1	0945	17,634	*	4.0	*	16,669
5/16/2	1440	9,455	*	4.0	*	9,077
5/17/1	0855	19,144	*	5.4	*	18,110
5/17/2	1331	10,892	*	5.4	*	10,304
5/18/1	0844	18,000	*	6.1	*	16,902

(continued)

TABLE B-4. (continued)

Date mo/day/no.	Pellet input dry basis (lb/hr)	Carbon input (lb/hr)	Hydrogen input (lb/hr)	Sulfur input (lb/hr)	Oxygen in fuel input (lb/hr)	Nitrogen in fuel input (lb/hr)
201	208	209	210	211	212	213
3/5/1	*	4,533	315	275	384	70
3/6/1	*	6,678	464	405	566	103
3/6/2	*	8,533	593	517	723	132
3/7/1	*	10,264	713	622	869	158
3/7/2	*	11,234	781	681	951	173
3/8/1	*	13,400	931	812	1,135	207
3/8/2	*	12,860	894	779	1,089	199
3/9/1	*	12,585	875	763	1,089	194
3/9/2	*	12,630	878	765	1,070	195
3/12/1	6,078	13,314	1,038	1,154	2,054	205
3/12/2	5,115	6,331	534	464	1,425	97
3/13/1	7,600	10,402	862	793	2,179	159
3/14/1	6,236	9,553	778	757	1,851	147
3/15/1	8,607	13,078	1,067	1,033	2,549	201
3/16/1	7,967	12,153	991	961	2,362	186
4/18/1	6,896	10,599	944	259	3,020	152
4/18/2	9,314	12,393	1,140	291	3,886	173
4/19/1	8,598	12,150	1,102	291	3,658	171
4/20/1	5,584	8,447	755	206	2,432	121
4/21/1	4,515	6,426	582	154	1,926	91
4/23/1	6,711	8,810	813	206	2,788	122
4/23/2	9,538	12,540	1,157	293	3,964	174
4/24/1	8,772	12,808	1,153	309	3,774	182
5/7/1	4,866	6,187	560	105	2,116	87
5/8/1	8,073	10,513	945	180	3,543	148
5/9/1	9,741	12,578	1,133	215	4,261	177
5/9/2	5,427	6,821	619	115	2,350	95
5/10/1	10,211	12,666	1,153	213	4,400	177
5/10/2	4,563	9,055	739	175	2,405	138
5/11/1	17,604	15,550	1,574	218	6,772	196
5/11/2	14,602	12,933	1,308	182	5,621	163
5/14/1	*	5,577	364	156	502	93
5/15/1	*	7,519	490	210	676	126
5/16/1	*	12,472	831	348	1,122	208
5/16/2	*	6,791	443	190	611	113
5/17/1	*	13,550	884	378	1,219	226
5/17/2	*	7,709	503	215	693	129
5/18/1	*	12,646	825	353	1,138	211

(continued)

TABLE B-4. (continued)

Date mo/day/no.	Ash input (lb/hr)	Heat input (MMBtu/ hour)	Moisture input (lb/hr)	Weight as received substitution (% dRDF)	Heat input substitution (% dRDF)
201	214	215	216	217	218
3/5/1	1,032	81.6	422	0	0
3/6/1	1,520	120.2	644	0	0
3/6/2	1,942	153.5	823	0	0
3/7/1	2,336	187.4	1,339	0	0
3/7/2	2,557	202.1	1,465	0	0
3/8/1	3,050	241.1	1,817	0	0
3/8/2	2,927	231.4	1,744	0	0
3/9/1	2,865	226.4	2,019	0	0
3/9/2	2,875	227.3	2,026	0	0
3/12/1	4,902	238.5	2,394	30	17
3/12/2	2,762	112.0	1,623	48	30
3/13/1	4,383	184.5	2,196	44	28
3/14/1	3,881	169.9	3,407	43	24
3/15/1	5,326	232.6	2,809	40	26
3/16/1	4,944	216.1	3,561	41	25
4/18/1	2,299	186.6	3,738	39	30
4/18/2	2,759	218.3	4,861	52	35
4/19/1	2,675	213.9	4,790	50	34
4/20/1	1,838	148.7	3,282	49	31
4/21/1	1,413	113.1	8,293	34	31
4/23/1	1,966	155.2	3,346	52	36
4/23/2	2,798	220.8	4,757	52	36
4/24/1	2,803	225.5	5,177	50	32
5/7/1	1,187	109.0	1,604	52	37
5/8/1	2,002	185.2	2,379	49	35
5/9/1	2,402	221.6	2,854	50	35
5/9/2	1,314	120.2	1,572	51	36
5/10/1	2,451	223.2	2,202	51	37
5/10/2	1,535	159.2	1,213	35	23
5/11/1	3,410	274.6	3,735	65	52
5/11/2	2,833	228.4	3,101	65	51
5/14/1	750	99.0	631	0	0
5/15/1	1,011	133.5	585	0	0
5/16/1	1,677	221.4	695	0	0
5/16/2	913	120.6	378	0	0
5/17/1	1,822	240.5	1,034	0	0
5/17/2	1,037	136.8	588	0	0
5/18/1	1,700	224.5	1,098	0	0

(continued)

TABLE B-4. (continued)

Date mo/day/no.	Bottom ash unburnt carbon (lb/hr)	Fly ash unburnt carbon (lb/hr)
201	219	220
3/5/1	101.0	83.2
3/6/1	84.0	69.7
3/6/2	105.1	101.0
3/7/1	237.4	73.7
3/7/2	227.7	187.7
3/8/1	282.9	131.0
3/8/2	221.7	280.6
3/9/1	241.7	150.9
3/9/2	272.3	55.6
3/12/1	266	323
3/12/2	159	96.5
3/13/1	309.5	72.9
3/14/1	256.9	123.1
3/15/1	753.1	170.0
3/16/1	629.7	60.0
4/18/1	208.9	135.0
4/18/2	259.6	136.2
4/19/1	507.6	184.4
4/20/1	162.9	129.7
4/21/1	122.9	87.1
4/23/1	187.7	102.3
4/23/2	257.7	177.1
4/24/1	286.1	118.1
5/7/1	204.9	41.0
5/8/1	209.5	83.9
5/9/1	209.9	73.4
5/9/2	115.1	39.7
5/10/1	127.4	164.0
5/10/2	89.0	60.3
5/11/1	29.2	88.3
5/11/2	25.1	64.3
5/14/1	59.1	92.9
5/15/1	36.7	142.5
5/16/1	180.2	340.8
5/16/2	90.3	218.6
5/17/1	171.9	348.3
5/17/2	100.1	185.5
5/18/1	165.1	240.2

(continued)

TABLE B-4. (continued)

Efficiency test No. mo/day/no. 221	Time start 222	Time end 223	Δt (hr) 224	Fuel input dry basis (lb/hr) 225	Heat input (MMBtu/ hour) 226	Feedwater input (10^3-lb) 227
3/5/1	1615	3230	16.25	6,618	81.6	1,070
3/6/1	0830	1230	4.00	9,751	120.2	300
3/6/2	1230	3300	20.50	12,459	153.5	1,990
3/7/1	0900	1305	4.08	14,986	184.7	490
3/7/2	1305	3255	19.83	16,402	202.1	2,710
3/8/1	0855	1335	4.67	19,565	241.1	680
3/8/2	1335	3320	19.75	18,777	231.4	2,950
3/9/1	0920	1335	4.30	18,375	226.4	640
3/9/2	1338	2605	12.45	18,441	227.3	1,780
3/12/1	1100	1700	6.00	22,706	238.5	---
3/12/2	1700	3315	16.25	11,637	112.0	---
3/13/1	0915	3630	27.25	18,815	184.5	3,020
3/14/1	1230	3700	24.50	16,999	169.9	2,670
3/15/1	1300	3300	20.00	23,298	232.6	2,430
3/16/1	0900	2300	14.00	21,639	216.1	1,960
4/18/1	0910	1303	3.95	17,339	186.6	450
4/18/2	1303	3230	20.11	20,724	218.3	2,660
4/19/1	0827	3526	27.18	20,926	213.9	3,550
4/20/1	1126	3200	20.57	13,851	148.7	1,930
4/21/1	0800	1558	7.92	10,632	113.1	470
4/23/1	0927	1345	4.30	14,764	155.2	420
4/23/2	1345	3555	22.17	21,010	220.8	3,170
4/24/1	1155	3545	23.88	21,111	225.5	3,410
5/7/1	1430	3710	22.67	10,287	109.0	---
5/8/1	1310	3405	20.92	17,406	185.2	---
5/9/1	1005	1516	5.18	20,856	221.6	---
5/9/2	1516	3245	17.48	11,364	120.2	---
5/10/1	0845	1300	4.25	21,153	223.2	---
5/10/2	1300	3030	17.50	14,096	159.2	---
5/11/1	0900	1000	1.00	27,871	274.6	---
5/11/2	1000	2000	9.87	23,165	228.4	---
5/14/1	1305	3320	20.25	7,454	99.0	1,360
5/15/1	0920	1430	5.17	10,049	133.5	2,110
5/15/2	1430	3345	19.25	†		
5/16/1	0945	1440	4.92	16,669	221.4	710
5/16/2	1440	3255	18.25	9,077	120.6	1,750
5/17/1	0855	1331	4.60	18,110	240.5	640
5/17/2	1331	3244	19.22	10,304	136.8	1,830
5/18/1	0844	---	4.17*	16,902	224.5	730

* Assumed

(continued)

TABLE B-4. (continued)

Efficiency test No. mo/day/no.	Feedwater input minus blowdown (10^3-lb)	Steam output integrator (10^3-lb)	Steam generation rate (10^3-lb/hr)	Steam enthalpy gain (Btu/lb)	Measured steam heat output (MMBtu/hr)
221	228	229	230	231	232
3/5/1	1,040	1,060	64	1,176.3	75.3
3/6/1	290	280	73	1,171.2	85.5
3/6/2	1,940	2,140	95	1,171.2	111.3
3/7/1	480	470	118	1,200.4	134.2
3/7/2	2,640	2,750	133	1,200.4	159.7
3/8/1	660	700	141	1,210.4	170.7
3/8/2	2,880	2,970	146	1,210.4	176.7
3/9/1	620	660	144	1,208.4	174.0
3/9/2	1,740	2,300	140	1,208.4	169.2
3/12/1	---	400	64	1,[illegible]63.2	74.4
3/12/2	---	1,820	107	1,163.2	124.5
3/13/1	2,940	2,980	108	1,193.3	128.9
3/14/1	2,600	2,730	106	1,204.3	127.7
3/15/1	2,370	2,420	119	1,205.4	143.4
3/16/1	1,910	2,010	136	1,202.4	163.5
4/18/1	440	430	111	1,194.2	132.6
4/18/2	2,590	2,570	129	1,194.2	154.1
4/19/1	3,460	3,520	127	1,214.2	154.2
4/20/1	1,880	1,840	91	1,208.4	110.0
4/21/1	460	440	58	1,174.3	68.1
4/23/1	410	420	95	1,200.3	114.0
4/23/2	3,090	3,140	139	1,200.3	166.8
4/24/1	3,320	3,280	139	1,220.4	169.6
5/7/1	---	2,330	98	1,240.9	121.6
5/8/1	---	2,300	105	1,215.3	127.6
5/9/1	---	760	140	1,223.4	171.3
5/9/2	---	1,230	67	1,223.4	82.0
5/10/1	---	714	161	1,221.4	196.5
5/10/2	---	2,360	129	1,221.4	157.6
5/11/1	---	130	124	1,214.4	150.6
5/11/2	---	---	---	1,214.4	---
5/14/1	1,330	1,340	66	1,182.2	78.0
5/15/1	2,060	2,150	84	1,196.3	100.9
5/15/2					
5/16/1	690	730	140	1,215.4	170.2
5/16/2	1,710	1,790	94	1,215.4	114.2
5/17/1	620	670	135	1,209.3	163.3
5/17/2	1,78[illegible]	1,850	93	1,209.3	112.5
5/18/1	710	670	139	1,214.4	168.8

(continued)

TABLE B-4. (continued)

Efficiency test No. mo/day/no.	Stoichiometric air requirement (dry weight) (lb/hr)	Excess air (%)	Air flow into boiler (10^3-lb/hr)	Bottom ash output (diff) (lb/hr)	Fly ash output (ESP index) (lb/hr)
221	233	234	235	236	237
3/5/1	9.44	95	121.8	988	228
3/6/1	9.44	106	189.6	1,405	269
3/6/2	9.44	106	242.3	1,758	390
3/7/1	9.44	86	263.1	2,374	273
3/7/2	9.44	86	288.0	2,277	695
3/8/1	9.44	42	262.3	2,938	526
3/8/2	9.44	42	251.7	2,302	1,127
3/9/1	9.44	64	284.5	2,642	616
3/9/2	9.44	64	285.5	2,976	227
3/12/1	8.15	83	338.6	4,610	880
3/12/2	7.48	83	159.3	2,754	263
3/13/1	7.61	47	210.5	4,428	337
3/14/1	7.76	90	250.6	3,665	596
3/15/1	7.75	86	335.8	5,391	858
3/16/1	7.75	53	256.6	5,314	320
4/18/1	8.22	54	219.5	2,098	554
4/18/2	8.02	54	262.3	2,596	559
4/19/1	7.80	55	253.0	2,610	757
4/20/1	8.20	54	174.9	1,563	558
4/21/1	8.12	216	272.8	1,229	394
4/23/1	8.01	136	279.1	1,877	379
4/23/2	8.01	136	397.2	2,577	656
4/24/1	8.15	68	289.1	2,686	521
5/7/1	7.95	135	192.2	1,328	105
5/8/1	7.98	70	236.1	1,967	328
5/9/1	7.97	54	256.0	2,330	355
5/9/2	7.93	54	138.8	1,277	192
5/10/1	7.91	84	307.9	2,041	701
5/10/2	8.51	84	220.7	1,426	258
5/11/1	7.35	47	301.1	2,732	796
5/11/2	7.36	47	250.6	2,342	580
5/14/1	10.09	108	156.4	594	308
5/15/1	10.08	55	157.0	685	504
5/15/2					
5/16/1	10.12	65	278.3	1,339	859
5/16/2	10.09	65	151.1	671	551
5/17/1	10.09	49	272.3	1,527	815
5/17/2	10.09	49	154.9	889	434
5/18/1	10.09	64	279.7	1,391	714

(continued)

TABLE B-4. (continued)

Efficiency test No. mo/day/no.	Total inerts input from ultimate analysis (lb/hr)	R/C energy percentage (%)	R/C energy losses (MMBtu/hr)
221	238	239	240
3/5/1	1,032	0.99	0.83
3/6/1	1,520	0.87	1.03
3/6/2	1,942	0.69	1.04
3/7/1	2,336	0.59	1.10
3/7/2	2,557	0.48	0.99
3/8/1	3,050	0.45	1.06
3/8/2	2,927	0.43	1.00
3/9/1	2,865	0.43	0.98
3/9/2	2,875	0.45	1.02
3/12/1	4,902	0.40	1.06
3/12/2	2,762	0.77	1.03
3/13/1	4,383	0.54	1.00
3/14/1	3,881	0.55	0.92
3/15/1	5,326	0.53	1.22
3/16/1	4,944	0.46	1.02
4/18/1	2,299	0.57	1.09
4/18/2	2,759	0.49	1.10
4/19/1	2,675	0.49	1.08
4/20/1	1,838	0.69	1.01
4/21/1	1,413	0.92	1.09
4/23/1	1,966	0.59	0.93
4/23/2	2,798	0.46	1.04
4/24/1	2,803	0.45	1.00
5/7/1	1,187	0.75	.81
5/8/1	2,002	0.59	1.11
5/9/1	2,402	0.45	1.00
5/9/2	1,314	0.92	1.11
5/10/1	2,451	0.47	1.02
5/10/2	1,535	0.70	1.08
5/11/1	3,410	0.40	1.09
5/11/2	2,833	0.40	0.91
5/14/1	750	0.92	0.89
5/15/1	1,011	0.80	1.05
5/15/2			
5/16/1	1,677	0.45	0.99
5/16/2	913	0.9	1.06
5/17/1	1,822	0.46	1.12
5/17/2	1,037	0.68	0.92
5/18/1	1,700	0.46	1.04

(continued)

TABLE B-4. (continued)

Efficiency test No. mo/day/no.	Input and output efficiency (%)	Boiler load (%)	Bottom ash heat loss (MMBtu/hr)	Fly ash heat loss (MMBtu/hr)	CO_2 output rate (lb/hr)
221	241	242	243	244	245
3/5/1	92	42	1.42	1.17	15,947
3/6/1	71	48	1.18	0.98	23,925
3/6/2	73	62	1.48	1.42	30,535
3/7/1	73	75	3.35	1.04	36,497
3/7/2	79	89	3.21	2.65	39,672
3/8/1	71	95	3.99	1.85	47,620
3/8/2	76	98	3.13	3.96	45,316
3/9/1	77	97	3.41	2.13	44,710
3/9/2	74	94	3.84	0.78	45,112
3/12/1	31	41	3.75	4.55	46,663
3/12/2	111	69	2.24	1.36	22,279
3/13/1	70	72	4.36	1.03	36,742
3/14/1	75	71	3.62	1.74	33,637
3/15/1	62	80	10.62	2.40	44,572
3/16/1	76	91	8.88	0.85	42,036
4/18/1	71	74	2.95	1.90	37,605
4/18/2	71	86	3.66	1.92	43,994
4/19/1	72	86	7.16	2.60	42,016
4/20/1	74	61	2.30	1.83	29,902
4/21/1	60	38	1.73	1.23	22,794
4/23/1	73	63	2.65	1.44	31,243
4/23/2	76	93	3.63	2.50	44,390
4/24/1	75	94	4.03	1.67	45,485
5/7/1	111	68	2.89	0.58	21,786
5/8/1	69	71	2.95	1.18	37,475
5/9/1	77	95	2.96	1.03	45,085
5/9/2	68	46	1.62	0.56	24,445
5/10/1	88	109	1.80	2.31	45,378
5/10/2	99	88	1.25	0.85	32,657
5/11/1	55	84	0.41	1.25	56,591
5/11/2	--	--	0.35	0.91	47,097
5/14/1	79	43	0.83	1.31	19,893
5/15/1	76	67	0.52	2.01	26,915
5/16/1	77	95	2.54	4.81	43,824
5/16/2	95	63	1.27	3.08	23,770
5/17/1	68	91	2.42	4.91	47,780
5/17/2	82	63	1.41	2.62	27,222
5/18/1	75	94	2.33	3.39	44,887

(continued)

TABLE B-4. (continued)

Efficiency test No. mo/day/no.	H_2O output rate (lb/hr)	SO_2 output rate (lb/hr)	Oxygen output rate (lb/hr)	N_2 output rate (lb/hr)	Economizer outlet temp. (°F)
221	246	247	248	249	250
3/5/1	3,257	550	14,375	93,491	400
3/6/1	4,820	810	23,232	145,527	395
3/6/2	6,160	1,034	29,719	185,976	395
3/7/1	7,756	1,244	29,312	201,957	410
3/7/2	8,494	1,362	32,284	221,070	410
3/8/1	10,196	1,624	19,371	201,392	435
3/8/2	9,790	1,558	18,859	193,253	435
3/9/1	9,894	1,526	27,110	218,406	420
3/9/2	9,928	1,530	27,006	219,174	420
3/12/1	11,736	2,308	37,566	259,911	385
3/12/2	6,429	928	16,609	122,280	415
3/13/1	9,954	1,586	16,825	161,613	425
3/14/1	10,409	1,514	28,806	192,357	430
3/15/1	12,412	2,066	38,818	257,760	430
3/16/1	12,480	1,922	22,701	196,998	435
4/18/1	12,234	518	19,014	168,509	415
4/18/2	15,121	582	23,607	201,357	430
4/19/1	14,708	582	20,334	194,222	440
4/20/1	10,077	412	15,199	134,269	420
4/21/1	13,531	308	44,107	209,329	400
4/23/1	10,663	412	38,395	214,192	410
4/23/2	15,170	586	54,691	304,826	435
4/24/1	15,554	618	28,534	221,922	435
5/7/1	6,644	210	26,475	147,504	395
5/8/1	10,884	360	23,570	181,237	430
5/9/1	13,051	430	21,853	196,529	440
5/9/2	7,143	230	11,852	106,555	420
5/10/1	12,579	426	33,714	236,336	440
5/10/2	7,864	350	23,999	169,415	440
5/11/1	17,901	436	22,977	231,140	440
5/11/2	14,873	364	19,125	192,373	440
5/14/1	3,907	312	19,413	120,052	415
5/15/1	4,995	420	13,560	120,545	425
5/16/1	8,174	696	27,110	213,664	455
5/16/2	4,365	380	14,803	116,007	430
5/17/1	8,990	774	22,479	209,080	445
5/17/2	5,115	430	12,755	118,937	425
5/18/1	8,523	706	26,722	214,741	425

(continued)

TABLE B-4. (continued)

Efficiency test No. mo/day/no.	Total dry flue gas output (10^3-lb/hr)	Dry flue gas loss (MMBtu/hr)	Enthalpy in @ 1 psi flue gas moisture (Btu/lb)	Wet flue gas loss (MMBtu/hr)
221	251	252	253	254
3/5/1	124.4	9.95	1,241.8	3.92
3/6/1	193.5	15.24	1,239.5	5.79
3/6/2	247.3	19.47	1,239.5	7.40
3/7/1	269.0	22.16	1,246	9.37
3/7/2	294.4	24.25	1,246	10.26
3/8/1	270.0	23.88	1,254	12.40
3/8/2	259.0	22.91	1,254	11.90
3/9/1	291.7	24.74	1,251	12.00
3/9/2	292.8	24.83	1,251	12.04
3/12/1	346.4	26.44	1,235	14.05
3/12/2	163.1	13.63	1,249	7.79
3/13/1	216.8	18.65	1,254	12.10
3/14/1	256.3	22.36	1,256	12.68
3/15/1	343.2	29.94	1,256	15.12
3/16/1	263.7	23.32	1,258	15.23
4/18/1	225.6	18.86	1,249	14.82
4/18/2	269.5	23.51	1,256	18.42
4/19/1	257.2	23.06	1,260	17.97
4/20/1	179.8	15.25	1,251	12.22
4/21/1	276.5	22.11	1,242	16.29
4/23/1	284.2	23.41	1,246	12.88
4/23/2	404.5	35.77	1,258	18.51
4/24/1	296.6	26.23	1,258	18.98
5/7/1	196.0	15.43	1,240	7.99
5/8/1	242.6	21.16	1,256	13.26
5/9/1	263.9	23.66	1,260	15.95
5/9/2	143.1	12.14	1,251	8.66
5/10/1	315.9	28.32	1,260	15.37
5/10/2	226.4	20.30	1,260	9.61
5/11/1	311.1	27.89	1,260	21.88
5/11/2	259.0	23.22	1,260	18.17
5/14/1	159.7	13.35	1,249	4.73
5/15/1	161.9	13.93	1,254	6.07
5/16/1	285.3	26.61	1,267	10.05
5/16/2	155.0	13.52	1,256	5.32
5/17/1	327.9	29.79	1,263	11.01
5/17/2	159.3	13.70	1,254	6.22
5/18/1	287.1	24.70	1,254	10.36

(continued)

TABLE B-4. (continued)

Efficiency test No. mo/day/no.	Extra (MMBtu/ hour)	Calculated boiler outlet H_2O (% vol)	Total losses (MMBtu/ hour)	Heat balance efficiency (%)	Heat input (MMBtu/ hour)
221	255	256	257	258	262
3/5/1	*	4.12	17.29	78.8	81.6
3/6/1	*	3.92	24.22	79.9	120.2
3/6/2	*	3.92	30.80	79.9	153.5
3/7/1	*	4.51	37.02	79.9	184.7
3/7/2	*	4.52	41.36	79.5	202.1
3/8/1	*	5.83	43.18	82.1	241.1
3/8/2	*	5.84	42.90	81.5	231.4
3/9/1	*	5.27	43.26	80.9	226.4
3/9/2	*	5.27	42.51	81.3	227.3
3/12/1	*	5.26	49.85	79.1	238.5
3/12/2	*	6.07	26.05	76.7	112.0
3/13/1	*	7.00	37.14	79.9	184.5
3/14/1	*	6.24	41.32	75.7	169.9
3/15/1	*	5.60	59.30	74.5	232.6
3/16/1	*	7.20	49.30	77.2	216.1
4/18/1	*	8.16	39.62	78.8	186.6
4/18/2	*	8.42	48.61	77.7	218.3
4/19/1	*	8.57	51.87	75.8	213.9
4/20/1	*	8.41	32.61	78.1	148.7
4/21/1	*	7.43	42.45	62.5	113.1
4/23/1	*	5.79	41.31	73.4	155.2
4/23/2	*	5.79	61.45	72.2	220.8
4/24/1	.76	7.92	52.67	76.6	225.5
5/7/1	*	5.26	27.70	74.6	109.0
5/8/1	*	6.85	39.66	78.6	185.2
5/9/1	*	7.50	44.60	79.9	221.6
5/9/2	*	7.56	24.09	80.0	120.2
5/10/1	*	6.13	48.82	78.1	223.2
5/10/2	*	5.39	33.09	79.2	159.2
5/11/1	.79	8.62	53.31	80.6	274.6
5/11/2	.79	8.60	44.35	80.6	228.4
5/14/1	*	3.86	21.11	78.7	99.0
5/15/1	*	4.81	28.39	78.7	133.5
5/16/1	*	4.49	45.00	79.7	221.4
5/16/2	*	4.41	24.25	79.9	120.6
5/17/1	*	4.30	49.25	79.5	240.5
5/17/2	*	5.00	24.87	81.8	136.8
5/18/1	1.62	4.64	43.44	80.7	224.5

(continued)

TABLE B-4. (continued)

Efficiency test No. mo/day/no.	R/C loss (%)	Bottom ash loss (%)	Fly ash loss (%)	Dry flue gas loss (%)	Wet flue gas loss (%)	Loss (%)
221	263	264	265	266	267	268
3/5/1	0.99	1.74	1.43	12.19	4.80	21.19
3/6/1	0.87	0.98	0.82	12.68	4.82	20.15
3/6/2	0.69	0.96	0.93	12.68	4.82	20.07
3/7/1	0.59	1.81	0.56	12.00	5.07	20.04
3/7/2	0.48	1.59	1.31	12.00	5.08	20.47
3/8/1	0.45	1.65	0.77	9.90	5.14	17.91
3/8/2	0.43	1.35	1.71	9.90	5.14	18.54
3/9/1	0.43	1.51	0.94	10.93	5.30	19.11
3/9/2	0.45	1.69	0.34	10.92	5.30	18.70
3/12/1	0.40	1.57	1.91	11.09	5.89	20.90
3/12/2	0.77	2.00	1.21	12.17	6.96	23.26
3/13/1	0.54	2.36	0.56	10.11	6.56	20.13
3/14/1	0.55	2.13	1.02	13.16	7.46	24.32
3/15/1	0.53	4.57	1.03	12.87	6.50	25.49
3/16/1	0.46	4.11	0.39	10.79	7.05	22.81
4/18/1	0.57	1.58	1.02	10.11	7.94	21.23
4/18/2	0.49	1.68	0.88	10.77	8.44	22.27
4/19/1	0.49	3.35	1.22	10.78	8.40	24.25
4/20/1	0.69	1.55	1.23	10.26	8.22	21.93
4/21/1	0.92	1.53	1.09	19.55	14.40	37.53
4/23/1	0.59	1.71	0.93	15.08	8.30	26.62
4/23/2	0.46	1.64	1.13	16.20	8.38	27.83
4/24/1	0.45	1.79	0.74	11.63	8.42	23.36
5/7/1	0.75	2.65	0.53	14.16	7.33	25.41
5/8/1	0.59	1.59	0.64	11.43	7.16	21.41
5/9/1	0.45	1.34	0.46	10.68	7.20	20.13
5/9/2	0.92	1.35	0.47	10.10	7.20	20.04
5/10/1	0.47	0.81	1.03	12.69	6.89	21.87
5/10/2	0.70	0.79	0.53	12.75	6.04	20.79
5/11/1	0.40	0.15	0.46	10.16	7.97	19.41
5/11/2	0.40	0.15	0.40	10.17	7.96	19.42
5/14/1	0.92	0.84	1.32	13.48	4.78	21.32
5/15/1	0.80	0.39	1.51	10.43	4.55	21.27
5/16/1	0.45	1.15	2.17	12.02	4.54	20.33
5/16/2	0.90	1.05	2.55	11.21	4.41	20.11
5/17/1	0.46	1.01	2.04	12.39	4.58	20.48
5/17/2	0.68	1.03	1.92	10.01	4.55	18.18
5/18/1	0.46	1.04	1.51	11.00	4.61	19.35

(continued)

TABLE B-4. (continued)

Efficiency test No. mo/day/no.	Efficiency (%)	Inert rate input (lb/10^6 Btu)	Sulfur rate input (lb/10^6 Btu)	N rate input (lb/10^6 Btu)
221	269	270	271	272
3/5/1	78.8	12.64	3.37	0.86
3/6/1	79.9	12.64	3.37	0.86
3/6/2	79.9	12.65	3.36	0.86
3/7/1	79.9	12.65	3.36	0.86
3/7/2	79.5	12.65	3.37	0.86
3/8/1	82.1	12.65	3.37	0.86
3/8/2	81.5	12.65	3.37	0.86
3/9/1	80.9	12.65	3.37	0.86
3/9/2	81.3	12.65	3.37	0.86
3/12/1	79.1	20.55	4.83	0.86
3/12/2	76.7	24.66	4.14	0.87
3/13/1	79.9	23.75	4.30	0.86
3/14/1	75.7	22.84	4.45	0.86
3/15/1	74.5	22.90	4.44	0.86
3/16/1	77.2	22.88	4.45	0.86
4/18/1	78.8	12.32	1.39	0.81
4/18/2	77.7	12.64	1.33	0.79
4/19/1	75.8	12.51	1.36	0.80
4/20/1	78.1	12.36	1.38	0.81
4/21/1	62.5	12.49	1.36	0.80
4/23/1	73.4	12.67	1.33	0.79
4/23/2	72.2	12.67	1.33	0.79
4/24/1	76.6	12.43	1.37	0.81
5/7/1	74.6	10.89	0.96	0.80
5/8/1	78.6	10.81	0.97	0.80
5/9/1	79.9	10.84	0.97	0.80
5/9/2	80.0	10.93	0.96	0.79
5/10/1	78.1	10.98	0.95	0.79
5/10/2	79.7	9.64	1.10	0.87
5/11/1	80.6	12.42	0.79	0.71
5/11/2	80.6	12.40	0.80	0.71
5/14/1	78.7	7.57	1.57	0.94
5/15/1	78.7	7.57	1.57	0.94
5/16/1	79.7	7.57	1.57	0.94
5/16/2	79.9	7.57	1.57	0.94
5/17/1	79.5	7.57	1.57	0.94
5/17/2	81.8	7.58	1.57	0.94
5/18/1	80.7	7.57	1.57	0.94

APPENDIX C

FORMULAE

The following equation sets demonstrate the calculations used to derive the data columns of Appendix B. For each column of Appendix B the corresponding equation in this Appendix provides the following information:

Title of data column and units	Formulae on which calculation is based
Manipulation of other data columns to produce this column	Definitions of terms used in formulae

THE FOLLOWING COLUMNS REPRESENT METHOD 5 TIME PERIODS

Data column	Description Column manipulation	Formula Sources
1	Date (month/day/AM or PM)	-------
	-------	Method 5 data sheets
2	Boiler load (steaming rate) (kilo-pounds/hour)	$W_{SE} = \frac{(SIF - SIS) \times 1750 \times .957}{\Delta t}$
	-------	SIF = Steam Integrator Finish reading SIS = Steam Integrator Start reading 1750 = Integrator readout multiplier .957 = Steam integrator calibration factor (water integrator as standard at 2 1/2 percent blowdown) Δt = Elapsed time of Method 5 test (hour)

2A Boiler load (percent of capacity) (%)

$$L = \frac{W_{SE} \times 100}{150,000}$$

$\frac{2}{1,500}$

L = Boiler load (% maximum rated capacity)

3 DRDF heat input substitution (% dRDF)

$$Q_f = (CF3)(WO3)(1-m_{ff})(H_{ff})$$

$$Q_c = \left[(CF5)(WO5) - (CF3)(WO3)\right](1-m_{fc})(H_{fc})$$

$$f_R = (100)\frac{Q_R}{Q_R + Q_C}$$

$$\frac{\underline{208} \div \underline{113} \times 100}{\underline{208} + \underline{113} + \underline{207} + \underline{95}}$$

f_R = dRDF heat substitution

Q_f = dRDF heat input (Btu)

Q_c = coal heat input (Btu)

WO3 = belt scale weight (dRDF)

WO5 = belt scale weight of coal + dRDF

CF3 = Belt No. 3 correction factor 1.036

CF5 = Belt No. 5 correction factor 1.166

m_{ff} = moisture fraction of as received - dRDF

m_{fc} = moisture fraction of as received - Coal

H_{ff} = higher heating value dRDF (Btu/lb)

H_{fc} = higher heating value coal (BTU/lb)

4 Fly ash reinjection
on
off

On = operation normal by reinjecting with overfire air all fly ash captured by skimmer baffle and multiclone dust collectors.

Off = reinjection of skimmer baffle fly ash continues, but multiclone fly ash is collected and removed.

5 CO_2 concentration
at ESP outlet
(%)

$$CO_2 = \frac{\text{Volume } CO_2 \times 100}{\text{Volume dry flue gas}}$$

NDIR continuous CO_2 monitor. Number reported is average of instantaneous readings taken at 5-minute intervals during Method 5 test period.

6 O_2 concentration
at ESP outlet
(%)

$$O_2 = \frac{\text{Volume } O_2 \times 100}{\text{Volume dry flue gas}}$$

Electrochemical cell analyzer number reported is average of instantaneous readings taken at 5-minute intervals during Method 5 test period.

$\underline{7}$ Excess air at ESP outlet (%)

$$EA = \frac{O_2 - .5CO}{.264\ N_2 - (O_2 - .5CO)}$$

$$\frac{\underline{6}}{.264\ (100 - \underline{5} - \underline{6}) - \underline{6}}$$

$N_2 = 100 - CO_2 - O_2$

CO negligible

$\underline{8}$ CO concentration at ESP outlet (50% EA) (ppm)

$$CO = \frac{\text{Volume CO} \times 10^6 \times (100 + EA)}{\text{Volume dry flue gas} \times 150}$$

Actual concentration = $\underline{53}$

NDIR continuous CO monitor number reported is average of instantaneous readings taken at 5-minute intervals during Method 5 test period. Adjusted to 50 Percent excess air

$\underline{9}$ NO_x concentration at ESP Outlet (50% EA) (ppm)

$$NO_x = \frac{\text{Volume } NO_2 \times 10^6 \times (100 + EA)}{\text{Volume dry flue gas} \times 150}$$

Actual concentration = $\underline{53}$

Determined by EPA Method 7 analysis, average of triplicate. Adjusted to 50 percent excess air

10 SO_x concentration at ESP outlet (50% EA) (ppm)

$$SO_x = \frac{\text{Volume } SO_2 \times 10^6 \times (100 + EA)}{\text{Volume dry flue gas} \times 150}$$

Actual concentration × 53

Electrochemical cell analyzer number reported is average of instantaneous readings taken at 5-minute intervals during Method 5 test period. Adjusted to 50 percent excess air.

11 Chloride concentration at ESP inlet (50% EA) (ppm)

$$Cl^- = \frac{\text{Volume } Cl^- \times 10^6 \times (100 + EA)}{\text{Volume dry flue gas} \times 150}$$

---

24 × 53

Determined by specific ion electrode analysis of Method 5 impinger solutions. Adjusted to 50 percent excess air.

12 Fluoride concentration at ESP inlet (50% EA) (ppm)

$$F^- = \frac{\text{Volume } F^- \times 10^6 \times (100 + EA)}{\text{Volume dry flue gas} \times 150}$$

---

24 × 53

Determined by specific ion electrode analysis of Method 5 impinger solutions. Adjusted to 50 percent excess air.

13	Particulate concentration at ESP inlet (50% EA) (gr/DSCF)	$C_{sc} = \frac{\text{Captured particlate} \times (100 + EA)}{\text{Measured dry gas volume} \times 150}$
	Measured concentration × 53	Standard EPA Method 5 sample analysis and calculations. Adjusted to 50 percent excess air.
14	Particulate concentration at ESP outlet (50 percent EA) (gr/DSCF)	Same as 13
	Measured concentration × 53	Measured at full load only. Adjusted to 50 percent excess air.
15 16	Particulate size distribution at ESP inlet or outlet ($D_{63.2\%}$ - n)(μm)	$Y = 1 - e^{-\left(\frac{D}{\bar{D}}\right)^{n}}$ Y = percent larger than D $\bar{D} = D_{63.2\%}$
	--------	$D_{63.2\%}$ = Intercept of Wiebul distribution plot n = Rosin-Rammler Exponent (slope of plot)

$\underline{17}$ Particulate emission
$\underline{18}$ at ESP inlet or outlet
($lb/10^6$ Btu)

$$Ep = \frac{Cs\ Fd\ (20.9)}{7000\ (20.9 - O_2)}$$

Cs = particulate concentration (gr/DSCF)

Fd = "F Factor" (DSCF/MMBtu)

7000 = grains/lb

O_2 = oxygen concentration

Ep = emission rate

Inlet:

$$\frac{\underline{13} \times \underline{59} \times 20.9}{\underline{53} \times 7000 \times (20.9 - \underline{6})}$$

Outlet:

$$\frac{\underline{14} \times \underline{59} \times 20.9}{\underline{53} \times 7000 \times (20.9 - \underline{6})}$$

$\underline{19}$ NO_x emission at
ESP outlet
($lb/10^6$ Btu)

$$E_{NO_x} = \frac{.1189 \times 10^{-6}\ NO_x\ Fd\ (20.9)}{(20.9 - O_2)}$$

$$\frac{\underline{9} \times .1189 \times 10^{-6} \times \underline{59} \times 20.9}{\underline{53} \times (20.9 - \underline{6})}$$

NO_x = NO_2 concentration (ppm)

Fd = "F Factor" (DSCF/10^6 Btu)

O_2 = oxygen concentration

$.1189 \times 10^{6} = \frac{lb/DSCF}{ppm}$ for NO_x

$\underline{20}$ SO_x emission at ESP outlet ($lb/10^6$ Btu)

$$E_{SO_x} = \frac{.1654 \times 10^{-6}\ SO_x\ Fd\ (20.9)}{(20.9 - O_2)}$$

$$\frac{\underline{10} \times .1654 \times 10^{-6} \times \underline{59} \times 20.9}{\underline{53} \times (20.9 - \underline{6})}$$

SO_x = SO_2 concentration (ppm)

Fd = "F Factor" ($DSCF/10^6$ Btu)

O_2 = oxygen concentration

$.1654 \times 10^{-6} = \frac{lb/DSCF}{ppm}$ for SO_x

$\underline{20A}$ CO emission at ESP outlet ($lb/10^6$ Btu)

$$E_{CO} = \frac{.7235 \times 10^{-7}\ CO\ Fd\ (20.9)}{(20.9 - O_2)}$$

$$\frac{\underline{8} \times .7235 \times 10^{-7} \times \underline{59} \times 20.9}{\underline{53} \times (20.9 - \underline{6})}$$

CO = CO concentration (ppm)

Fd = "F Factor" ($DSCF/10^6$ Btu)

O_2 = oxygen concentration (%)

$.7235 \times 10^{-7} = \frac{lb/DSCF}{ppm}$ for CO

20B Cl⁻ emission at ESP inlet (lb/10⁶ Btu)

$$E_{Cl} = \frac{.8785 \times 10^{-7}\ Cl^{-}\ Fd\ (20.9)}{(20.9 - O_2)}$$

$$\frac{\underline{24} \times .8785 \times 10^{-7} \times \underline{59} \times 20.9}{(20.9 - \underline{6})}$$

Cl^- = chloride concentration (ppm)

Fd = "F Factor" (DSCF/10^6 Btu)

O_2 = oxygen concentration (%)

$.8785 \times 10^{-7} = \frac{\text{lb/DSCF}}{\text{ppm}}$ for chlorine

20C F⁻ emission at ESP inlet (lb/10⁶ Btu)

$$E_F = \frac{.4651 \times 10^{-7}\ F^{-}\ Fd\ (20.9)}{(20.9 - O_2)}$$

$$\frac{\underline{26} \times .4551 \times 10^{-7} \times \underline{59} \times 20.9}{(20.9 - \underline{6})}$$

F^- = fluoride concentration (ppm)

Fd = "F Factor" (DSCF/10^6 Btu)

O_2 = oxygen concentration (%)

$.4651 \times 10^{-7} = \frac{\text{lb/DSCF}}{\text{ppm}}$ for fluorine

20D Ash release rate at ESP inlet (%)

$$\varepsilon_{ash} = \frac{E_p \times 100}{A_I}$$

$$\frac{\underline{17} \times 100}{\underline{270}}$$

ε_{ash} = percent of ash released as particulate

E_p = particulate emisstion rate (lb/10^6 Btu)

A_I = ash input rate (lb/10^6 Btu)

20E Sulfur release rate at ESP outlet (%)

$$\varepsilon_{SO_x} = \frac{E_{SO_x} \times 100}{A_S \times 2}$$

$$\frac{\underline{20} \times 100}{\underline{2} \times \underline{270}}$$

ε_{SO_x} = percent of maximum possible sulfur dioxide release

E_{SO_x} = SO_2 emission (lb/10^6 Btu)

A_S = sulfur input (lb/10^6 Btu)

20F NO_x release rate at ESP outlet (%)

$$\varepsilon_{NO_x} = \frac{E_{NO_x} \times 100}{A_N \times 3.43}$$

$$\frac{\underline{19} \times 100}{3.43 \times \underline{272}}$$

ε_{NO_x} = percent of maximum possible NO_x release

E_{NO_x} = NO_x emission (lb/10^6 Btu)

A_N = nitrogen input rate (lb/10^6 Btu)

21 CO flow rate at ESP Outlet (lb/hr)

$$W_{co} = .7235 \times 10^{-7}\ CO\ V_{dfg}(60)$$

$$\frac{\underline{8} \times \underline{60}}{\underline{53}} \times 60 \times .7235 \times 10^{-7}$$

CO = measured CO concentration (ppm)

V_{dfg} = volume dry rule gas (DSCF/min)

$.7235 \times 10^{-7} = \frac{lb/dSCF}{ppm}$ for CO

60 = min/hr

22
23 H_2O concentration at ESP inlet or outlet (%)

$$H_2O = \frac{100\ V_{H_2O}}{V_{H_2O} + V_{dfg}}$$

V_{H_2O} = water vapor volume (SCF)

V_{dfg} = dry flue gas volume (dSCF)

Determined according to EPA Reference Method 5

24
25 Chloride concentration at ESP inlet or outlet (ppm)

$$Cl^- = \frac{V_{Cl^-} \times 10^6}{V_{dfg}}$$

V_{Cl^-} = volume chloride

V_{dfg} = volume dry flue gas

Determined from specific ion electrode analysis of impinger solutions from Method 5

26
27 Fluoride concentration at ESP inlet or outlet (ppm)

$$F^- = \frac{V_{F^-} \times 10^6}{V_{dfg}}$$

V_{F^-} = volume of fluoride

V_{dfg} = volume dry flue gas

Determined from specific ion electrode analysis of impinger solutions from Method 5

28
29 SO_x concentration at ESP inlet or outlet (ppm)

$$C_{SO_2} = \frac{V_{SO_2} \times 10^6}{V_{dfg}}$$

V_{SO_2} = volume of SO_2

V_{dfg} = volume of dry flue gas

Barium perchlorate titration of 10% H_2O_2 impinger solutions from EPA Method 5. Used only as a check of electro-chemical cell analyzer.

30
31 Measured average velocity at ESP inlet or outlet (fpm)

$$\bar{V} = \frac{\sum_{i=1}^{n} \sqrt{\rho g h_i}}{n}$$

Average of pitot readings recorded with EPA Method 5.

$\bar{V}$ = average velocity

ρ = density of flue gas

h = pitot velocity pressure measured

n = number of traverse points

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$\underline{32}$ $\underline{33}$ Measured Gas Flow Rate at ESP Inlet or Outlet (scfm)

$$V_{wfgm} = \frac{V\ A\ (530)}{(460 + T_s)}$$

Inlet: $\dfrac{\underline{30} \times 65 \times 530}{(460 + \underline{34})}$

Outlet: $\dfrac{\underline{31} \times 65 \times 530}{(460 + \underline{35})}$

V_{wfgm} = volumetric flow rate total flue gas (at STP)

V = flue gas velocity at actual conditions

A = duct cross-sectional area

T_s = flue gas temperature

$\underline{34}$ $\underline{35}$ Measured gas temperature at ESP inlet or outlet (°F)

$$T_s = \frac{\sum_{i=1}^{n} (T_i)}{n}$$

T_s = average measured temperature

T_i = measured probe temperatures

n = number of traverse points

Average of readings recorded during EPA Method 5, accuracy ± 1 1/2 percent

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TYPING GUIDE SHEET

$\underline{36}$ $\underline{37}$ **Particulate rate at ESP inlet or outlet (lb/hr)**

$$W_p = \frac{C_{sc}\ V_{dfgm}}{7000}$$

Inlet: $\dfrac{\underline{13} \times \underline{32} \times (100 - \underline{22})}{\underline{53} \times 7000 \times 100}$

Outlet: $\dfrac{\underline{14} \times \underline{33} \times (100 - \underline{23})}{\underline{53} \times 7000 \times 100}$

Using standard EPA Method 5 calculations

C_{sc} = particulate concentration (gr/dSCF)

V_{dfgm} = measured volume of dry flue gas

7000 = grains/lb

$\underline{38}$ **NO_x flow rate at ESP outlet (lb/hr)**

$$W_{NO_x} = .1189 \times 10^{-6}\ NO_x\ V_{dfg}\ (60)$$

$$\frac{.1189 \times 10^{-6}\ \underline{9} \times \underline{60} \times 60}{\underline{53}}$$

NO_x = NO_2 concentration in dry flue gas

V_{dfg} = calculated volume of dry flue gas

$.1189 \times 10^{-6} = \dfrac{\text{lb/scf}}{\text{ppm}}$ for NO_2

60 = min/hr

39 SO_x flow rate at ESP outlet (lb/hr)

$$W_{SO_x} = .1654 \times 10^{-6}\ SO_x\ V_{dfg}\ (60)$$

$$\frac{.1654 \times 10^{-6} \times \underline{10} \times \underline{60} \times 60}{\underline{53}}$$

SO_x = SO_2 concentration in dry flue gas

V_{dfg} = calculated volume of dry flue gas

$.1654 \times 10^{-6} = \frac{\text{lb/scf}}{\text{ppm}}$ for SO_2

60 = min/hr

40 Chloride flow rate at ESP inlet (lb/hr)

$$W_{Cl^-} = .8785 \times 10^{-7}\ Cl^-\ V_{dfg}\ (60)$$

$$.8785 \times 10^{-7} \times \underline{24} \times \underline{60} \times 60$$

Cl^- = chloride concentration in dry flue gas

V_{dfg} = calculated volume of dry rule gas

$.8785 \times 10^{-7} = \frac{\text{lb/scf}}{\text{ppm}}$ for chlorine

EPA Form 2360-4
TYPING GUIDE SHEET

$\underline{41}$ Fluoride flow rate at ESP inlet (lb/hr)

$$W_{F^-} = .4651 \times 10^{-7}\ F^-\ V_{dfg}\ (60)$$

$$.4651 \times 10^{-7} \times \underline{26} \times \underline{60} \times 60$$

F^- = fluoride concentration in dry flue gas

V_{dfg} = calculated volume of dry flue gas

$.4651 \times 10^{-7} = \frac{\text{lb/scf}}{\text{ppm}}$ for fluroine

$\underline{42}$ Opacity at economizer outlet (%)

Opacity = 1 - transmittance

From transmissometer reading at economizer outlet. Average of 1/2-hour readings during Method 5 tests.

$\underline{43}$ $\underline{48}$ ESP Performance Parameters
$\underline{44}$ $\underline{49}$
$\underline{45}$ $\underline{50}$
$\underline{46}$ $\underline{51}$
$\underline{47}$ $\underline{52}$

Direct measurement instruments. Average of 1/2-hour readings during Method 5 tests.

53 Excess air correction factor

$$CF = \frac{100 + EA}{150}$$

$$\frac{100 + \underline{7}}{150}$$

EA = excess air (%)

For adjustment of concentrations to 50% excess air

54 ESP Power Consumption (K - VA)

$$P_{ESP} = \frac{E_p i_p}{1000}$$

$$\frac{\underline{43} \times \underline{44} + \underline{48} \times \underline{49}}{1000}$$

P_{ESP} = precipitator power usage (KVA)

E_p = primary voltage

i_p = primary current

55 ESP pressure (inches H_2O)

$$P_{ESP} = \frac{\sum_{i=1}^{n} - P_i}{n}$$

Average of pressures read on 1/2-hour intervals during Method 5 test.

56 ESP efficiency (%)

$$\delta = \frac{E_{pi} - E_{po}}{E_{pi}} (100)$$

$$\frac{(\underline{17} - \underline{18}) \times 100}{\underline{17}}$$

δ = removal efficiency

E_{pi} = inlet particulate emissions

E_{po} = outlet particulate emissions

57
58 Method 5 times-start, stop

From EPA Reference Method 5 Data Sheets

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$\underline{59}$ "F-Factor"

$$F_d = \Sigma f_H F_d$$

$$F_d = 10^6 \; \frac{3.34H + 1.53C}{H_f} + \frac{.57S + .14N - .46 \times O}{H_f}$$

$$F_{dc} = \frac{3.34 \times \underline{87} + 1.53 \times \underline{88}}{\underline{95} \times 10^6} + \frac{.57 \times \underline{90} + .14 \times \underline{89} - .46 \times \underline{92}}{95 \times 10^6}$$

$$F_{dR} = \frac{3.34 \times \underline{107} + 1.53 \times \underline{108}}{\underline{115} \times 10^6} + \frac{.57 \times \underline{110} + .14 \times \underline{109} - .46 \times \underline{112}}{\underline{115} \times 10^6}$$

$$F_d = \frac{\underline{3}}{100} \times F_{dc} + \left(1 - \frac{\underline{3}}{100}\right) \times F_{dR}$$

F_d = "F Factor" ($ft^3/10^6$ Btu)

H = fuel hydrogen content

C = fuel carbon content

S = fuel sulfur content

N = fuel nitrogen content

O = fuel oxygen content

H_f = fuel higher heating value

f_H = fraction of heat input by each fuel

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60 Calculated ESP flow rate (DSCFM)

$$V_{dfg} = \frac{W_{SE}\,(h_s - h_w)\,F_d\,20.9}{60 \times 10^6\,(.79)\,(20.9 - O_2)}$$

$$\frac{\underline{2} \times 1000 \times 1200 \times \underline{59} \times 20.9}{60 \times 10^6 \times (20.9 - \underline{6}) \times .79}$$

V_{dfg} = calculated dry flue gas volume

W_{SE} = steam generation rate (lb/hr)

h_s = enthalpy of steam (Btu/lb)

h_w = enthalpy of water (Btu/lb)

F_d = "F Factor" ($ft^3/10^6$ Btu)

O_2 = flue gas oxygen concentration (%)

THE FOLLOWING COLUMNS ARE DAILY AVERAGES

61 Date (month/day) -------

-------　　　-------

62 Coal type -------

Designation of coal analysis with similar properties

63 Pellet type (manufacturer) -------

N = NCRR
T = Teledyne

----

64 Fly ash reinjection -------

See 4

65 Resistivity of ESP collect (ohm-cm)

$E = .9V_B$

$R = \frac{EA}{IL}$

According to ASME PTC28

E = applied voltage (volts)

I = current (amperes)

L = thickness of sample in instrument (cm)

A = cross-sectional area of sample in instrument (cm^2)

V_B = breakdown voltage of particulate

R = resistivity (ohm-cm)

EPA Form 2350-4 (3-66)
(PREVIOUSLY EIN. EPA FORM 381)
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66	Grate speed (ft/hr)	Grate speed = .0522 × drive pinion rpm
	-------	Average of hourly drive pinion speeds
67	Spreader rotor speed (rpm)	Rotor speed = 33/27 × drive shaft rpm
	-------	Average of hourly drive shaft speeds
68	Ash bed depth (in.)	-------
	-------	Average of hourly observations by visual estimate
69	Measured bottom ash weight (lb/hr)	$W_{dpem} = \frac{W_t - W_{tare}}{\Delta t}$
	-------	W_{dpem} = measured residue rate W_t = gross weight of truck load W_{tare} = truck tare weight Δt = elapsed time of weighed ash accumulation

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70 Bottom ash unburnt combustibles (%)

$$U_c = \frac{(1 - W_{ash})(100)}{W_{sample}}$$

U_c = unburnt combustibles (%)

W_{ash} = weight of inerts in dry sample (g)

W_{sample} = weight of dry sample (g)

71 Bottom Ash Fines (% < 1/4 in.)

$$\frac{(100)\text{ wt. fines}}{\text{Dry sample wt.}}$$

Sieve analysis of bottom ash composite sample

72 Fly ash rate boiler outlet (lb/hr)

$W_{fa} = Cs'W_{gf}(13.2)$

$Cs' \times \underline{173} \times 13.2$

W_{fa} = weight of fly ash (lb/hr)

Cs' = dust concentration from high volume sampler measurement (lb/SCF)

W_{fg} = total flue gas flow rate (lb/hr)

13.2 = specific volume flue gas (ft^3/lb)

73	Fly ash size boiler outlet ($D_{63.21}$)	See 15
	-------	-------
74	Unburnt combustibles at boiler outlet (%)	$100 - \frac{100\ (\text{wt. inerts})}{\text{Dry sample wt.}}$
	-------	From muffle furnace analysis of fly ash
75	Multiclone particulate collected (lb/hr)	$\frac{\text{Wt. fly ash collected}}{\Delta t}$
	-------	Δt = elapsed time of fly ash collection during bypass

EPA Form 2350-1 (4-80)

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76 Multiclone collect size distribution (% >90µ)

$$\frac{\text{Wt. } > 90\mu\text{m}}{\text{Total sample wt.}}$$

From sieve analysis

77 Multiclone collect unburnt combustibles (%)

$$(100)\left(1 - \frac{\text{Wt. inerts}}{\text{Wt. sample}}\right)$$

Muffle furnace analysis of fly ash sample

78 Particulate collection rate of ESP (lb/hr)

$$W_{pc} = W_{pi} - W_{po}$$

Average of 36 - 37

W_{pc} = weight of particulate collected (lb/hr)

W_{pi} = weight of particulate at inlet (lb/hr)

W_{po} = weight of particulate at outlet (lb/hr)

79 **Size distribution ESP collect (μm) mean** -------

------- Mean diameter from Coulter Counter analysis

---

80 **Unburnt combustibles ESP collect (%)**

$$(100)\left(1 - \frac{\text{Wt. inerts}}{\text{Wt. sample}}\right)$$

------- Muffle furnace analysis

---

81 **Coal "F Factor" (SCFM/10^6 Btu)** -------

------- See 59

EPA Form 2350-4 (4-30)
(PREVIOUSLY EPA FORM 243)
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82 Coal Type -------

------- Arbitrary designations based on sulfur content and ash free, moisture free heating value

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83 Coal Moisture (%)

$$m_{fc} = 100 - \frac{\text{Dry wt.}}{\text{A - R wt.}}$$

M_{fc} = coal moisture (% as received)

Dry wt. = dry wt. of moisture sample

A - R wt. = as received wt. of sample

84 85 86 87 88 89 90 91 92 Coal Properties (%)

$$\frac{\text{Wt. component} \times (100)}{\text{Wt. dry sample}}$$

------- From ultimate and proximate analysis reported on a dry weight basis

EPA Form 2350-9 (4-80)
(PREVIOUSLY CIN. EPA FORM 287)
TYPING GUIDE SHEET

93 Density of coal (lb/ft^3)

$$\rho_c = \frac{(G - T)\ 2.2046}{.668}$$

ρ_c = density of coal

G = gross wt. 5 gallon sample (kg)

T = tare wt. 5 gallon container (kg)

2.2046 = lb/kg

.668 = volume 5 gallon container (ft^3)

94 Coal fines (% < 1/4 in.)

$$\frac{(100)\ W_F}{W_T}$$

W_F = weight of fraction < 1/4 inch

W_T = total weight of as-received sample

95 Coal higher heating value (Btu/lb)

From adiabatic bomb calorimeter tests dry weight basis

EPA Form 2200-4 (4-80)

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96
97
98
99 Coal reducing fusion temperature analysis (°F)

Deformation temperatures of ashed fuel samples in reducing atmosphere

---

100 Coal ash free and moisture free heating value (Btu/lb)

$$\text{Btu} = \frac{\text{HHV}}{1 - \frac{a}{100}}$$

$$\frac{95}{1 - \frac{86}{100}}$$

HHV = heating value on dry basis

a = percent ash dry basis

100A Coal as received higher heating value (Btu/lb)

From adiabatic bomb calorimater tests determined on an as-received basis

101 **Pellet "F Factor"**

Same as 81

102 **Pellet Type** -------

N = NCRR

T = Teledyne

103 **Moisture (%)**

$$M_{fR} = 100 \quad 1 - \frac{\text{Dry wt.}}{\text{A - R wt.}}$$

M_{fR} = dRDF moisture (% as received)

Dry wt. = dry wt. of moisture sample

A - R wt. = as received weight of sample

104 109 Pellet properties (%)
105 110
106 111
107 112
108

$$\frac{\text{Wt. component}}{\text{Wt. dry sample}}$$

From ultimate and proximate analysis - dry weight basis

113 Density of dRDF (lb/ft^3)

$$\rho_R = \frac{(G - T)\ 2.2046}{.668}$$

ρ_R = density of dRDF

G = gross wt. of 5 gallon sample (kg)

T = tare wt. of 5 gallon container (kg)

2.2046 = lb/kg

.668 = volume (ft^3) of 5 gallon container

114 Pellet fines (% < 1/4 in.)

$$\frac{(100)\ W_F}{W_T}$$

W_F = Weight of fraction < 1/4 inch

W_T = total as-received weight of sample

115 Pellet higher heating value (Btu/lb)

From adiabatic bomb calorimeter tests

116
117
118
119 Pellet reducing fusion temperature analysis (°F)

Deformation temperatures of ashed fuel samples in reducing atmosphere

120 Pellet ash free moisture free heating value (Btu/lb)

$$\text{Btu} = \frac{\text{HHV}}{1 - \frac{a}{100}}$$

$$\frac{115}{1 - \frac{106}{100}}$$

HHV = pellet heating value on dry basis

a = percent ash dry basis

120A Pellet as-received higher heating value (Btu/lb)

From adiabatic bomb calorimeter tests calculated on an as-received basis

121 Date (month/day)

122 Elapsed time (hr)

$\Delta t = t_e - t_i$

---

223 - 222

Δt = elapsed time for day

t_i = time of first bunker loading on date

t_e = time of first bunker loading on next date

123 Coal input dry basis (lb/hr)

From 207

Average input during period sample collection

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124 Pellet input dry basis (lb/hr)

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From 208

Average input during period of sample collection

125 Calculated density (lb/ft^3)

$$\rho_B = \frac{W_C \rho_C + W_R \rho_R}{W_C + W_R}$$

$$\frac{\underline{123} \times \underline{93} + \underline{124} \times \underline{113}}{\underline{123} + \underline{124}}$$

ρ_B = calculated blend density

ρ_C = measured coal density

ρ_R = measured dRDF density

W_C = measured coal weight

W_R = measured dRDF weight

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(PREVIOUSLY EPA FORM 157)
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126 Measured blend density (lb/ft^3)

$$\rho_{Bm} = \frac{(G - T)\ 2.2046}{.668}$$

ρ_{Bm} = measured density of blend

G = gross weight 5 gallon sample (kg)

T = tare weight 5 gallon container (kg)

2.2046 = lb/kg

.668 = volume 5 gallon container (ft^3)

127 Calculated fixed carbon (%)

$$\frac{W_cFC_c + W_RFC_R}{W_C + W_R}$$

$$\frac{\underline{123} \times \underline{84} + \underline{124} \times \underline{104}}{\underline{123} + \underline{124}}$$

W_C = weight of coal (lb/hr)

W_R = weight of dRDF (lb/hr)

FC_c = coal fixed carbon (%)

FC_R = refuse fixed carbon (%)

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(PREVIOUSLY CIN. EPA FORM 261)
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128 Lab analysis fixed carbon (%)

From proximate analysis of composite blend samples

129 Blend calculated volatiles (%)

$$\frac{W_C \; VM_C + W_R \; VM_R}{W_C + W_R}$$

$$\frac{\underline{123} \times \underline{85} + \underline{124} \times \underline{105}}{\underline{123} + \underline{124}}$$

W_C = weight of coal (lb/hr)

W_R = weight of dRDF (lb/hr)

VM_C = coal volatile matter (%)

VM_R = dRDF volatile matter (%)

130 Volatiles lab analysis (%)

From proximate analysis of composite blend samples (dry basis)

131 Blend calculated ash (%)

$$\frac{W_C A_C + W_R A_R}{W_C + W_R}$$

$$\frac{\underline{123} \times \underline{86} + \underline{124} \times \underline{106}}{\underline{123} + \underline{124}}$$

W_C = weight of coal (lb/hr)

W_R = weight of dRDF (lb/hr)

A_C = ash content of coal (%)

A_R = ash content of dRDF (%)

132 Ash content lab analysis (%)

From proximate analysis of composite of blend samples (dry basis)

133 Blend calculated carbon (%)

$$\frac{W_C C_C + W_R C_R}{W_C + W_R}$$

$$\frac{\underline{123} \times \underline{88} + \underline{124} \times \underline{108}}{\underline{123} + \underline{124}}$$

W_C = weight of coal (lb/hr)

W_R = weight of dRDF (lb/hr)

C_C = coal carbon content (%)

C_R = dRDF carbon content (%)

134 Carbon content lab analysis (%)

From ultimate analysis of composite of blend samples (dry basis)

135 Blend calculated hydrogen (%)

$$\frac{W_C\, H_C + W_R\, H_R}{W_C + W_R}$$

$$\frac{\underline{123} \times \underline{87} + \underline{124} \times \underline{107}}{\underline{123} + \underline{124}}$$

W_C = weight of coal (lb/hr)

W_R = weight of dRDF (lb/hr)

H_C = coal hydrogen content (%)

H_R = dRDF hydrogen content (%)

136 Hydrogen content lab analysis of blend (%)

From ultimate analysis of composite blend sample (dry basis)

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137 Heating value calculated (Btu/lb)

$$\frac{W_C H_{fC} + W_R H_{fR}}{W_C + W_R}$$

$$\frac{\underline{123} \times \underline{95} + \underline{124} \times \underline{115}}{\underline{123} + \underline{124}}$$

W_C = weight of coal (lb/hr)

W_R = weight of dRDF (lb/hr)

H_{fC} = coal higher heating value (Btu/lb)

H_{fR} = dRDF higher heating value (Btu/lb)

138 Heating value of blend by lab analysis (Btu/lb)

From adiabatic bomb calorimeter test of composite blend sample (dry basis)

139 Sulfur content of blend calculated (%)

$$\frac{W_C\,S_C + W_R\,S_R}{W_C + W_R}$$

$$\frac{\underline{123} \times \underline{90} + \underline{124} \times \underline{110}}{\underline{123} + \underline{124}}$$

W_C = weight of coal (lb/hr)

W_R = weight of dRDF (lb/hr)

S_C = coal sulfur content (%)

S_R = dRDF sulfur content (%)

140 Sulfur content of blend by lab analysis (%)

From ultimate analysis of composite blend samples (dry basis)

141 Boiler load (10^3 lb/hr)

See 1

Average during period of ~ 8:00 AM to 6:00 PM. From steam or feedwater integrator.

142 Load swing frequency (hr^{-1}) -------

Average number of load swings from boiler chart during period ~ 8:00 AM to 6:00 PM.

143 Amplitude of load swing (10^3 lb/hr) -------

From boiler charts - average size of load swings during period ~ 8:00 AM to 6:00 PM.

144 Blend ratio by weight $\left(\frac{\text{lb - dRDF}}{\text{lb - coal}}\right)$

$$R_{wt} = \frac{W_{RA-R}}{W_{CA-R}}$$

$\frac{204}{203}$

W_{RA-R} = dRDF weight as received (lb/hr)

W_{CA-R} = coal weight as received (lb/hr)

145 Fly ash reinjection (on/off)

See Column 4

146 CO_2 concentration at boiler outlet (%)

$$CO_2 = \frac{\text{Volume } CO_2 \times 100}{\text{Volume dry flue gas}}$$

NDIR continuous CO_2 monitor. Value reported is average of instantaneous readings taken at 5 minute intervals between ~ 8:00 AM and 6:00 PM.

147 O_2 concentration at boiler outlet (%)

$$O_2 = \frac{\text{Volume } O_2 \times 100}{\text{Volume dry flue gas}}$$

Electrochemical cell analyzer number reported is average of instantaneous readings taken at 5 minute intervals between ~ 8:00 AM and 5:00 PM.

148 **Excess air at boiler outlet (%)**

$$EA = \frac{O_2 - .5\ CO}{.264\ N_2 - (O_2 - .5\ CO)}$$

$$\frac{\underline{147}}{.264\ (100 - \underline{146} - \underline{147}) - \underline{147}}$$

$N_2 = 100 - CO_2 - O_2$

CO is negligible

149 **CO at boiler outlet (ppm)**

$$CO = \frac{\text{Volume CO} \times 10^6}{\text{Volume dry flue gas}}$$

Continuous NDIR CO monitor. Value reported is average of instantaneous readings taken at 5 minute intervals between ~ 8:00 AM and 6:00 PM.

150 **ΔCO_2 at screen tubes (%)**

$$\sqrt{\left(CO_{2_L} - CO_{2_R}\right)^2}$$

Difference in CO_2 concentrations between left and right sides of the furnace as monitored by continuous NDIR's.

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151	Unburnt HC at boiler outlet (ppm)	$HC = \frac{\text{Volume HC} \times 10^6}{\text{Volume dry flue gas}}$
	-------	As determined from several grab samples analyzed on a gas chromatograph with a flame ionization detector.
152	Opacity at economizer outlet (%)	-------
	-------	From transmissiometer reading at economizer outlet. Average of 30 minute readings from ~ 8:00 AM to 6:00 PM.
153	Steam pressure (psig)	-------
	-------	From Bourdon gauge on steam drum. Average of 30 minute reading from 8:00 AM to 6:00 PM.

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154 Steam temperature (psig)

Average of 30 minute readings from control panel instrument measuring super heater outlet temperature ~ 8:00 AM to 6:00 PM.

155 Flame temperature (°F)

Average of optical pyrometer readings

156 Gas temperature super heater (°F)

Average of 30 minute readings taken with a nonaspirated type K thermocouple in super heater furnace section.

157 Gas temperature convective section (°F) -------

------- Average of 30 minute readings taken with a type K thermocouple in the convective boiler section.

158 Gas temperature boiler outlet (°F) -------

------- Average of 30 minute readings taken with a calibrated vapor pressure thermometer at the multiclone inlet.

159 Gas temperature economizer outlet (°F) -------

------- Average of 30 minute readings taken with a calibrated vapor pressure thermometer at the economizer outlet

160 Gas temperature
ESP inlet
(°F)

Average from Method 5 tests performed on date.

161 CO_2 boiler outlet
(%)

Same as 146

----

162 CO_2 ESP outlet
(%)

Daily averages as measured at ESP outlet on dry gas basis by NDIR.

163 O_2 boiler outlet
(%)

Same as 147

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164 O_2 ESP outlet (%) -------

------- Daily averages as measured by electrochemical cell at ESP outlet

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165 CO boiler outlet (ppm) -------

Same as 149 -------

166 CO ESP outlet (ppm) -------

------- Daily average as measured by NDIR at ESP outlet.

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167 NO_x boiler outlet (ppm)

$$\frac{\text{Volume } NO_2 \times 10^6}{\text{Volume dry flue gas}}$$

Daily average measured by electrochemical cell at the boiler outlet.

168 NO_x ESP outlet (ppm)

$$\frac{\text{Volume } NO_2 \times 10^6}{\text{Volume dry flue gas}}$$

Daily average measured by electrochemical cell at the ESP outlet.

169 SO_x boiler outlet (ppm)

$$\frac{\text{Volume } SO_x \times 10^6}{\text{Volume dry flue gas}}$$

Daily average measure by electrochemical cell at the boiler outlet.

170 SO_x ESP outlet (ppm)

$$\frac{\text{Volume } SO_x \times 10^6}{\text{Volume dry flue gas}}$$

Daily average measured by electrochemical cell at the ESP outlet.

171 Molecular weight boiler outlet flue gas (lb/mole)

$$MW_{fg} = \sum MW_i C_i$$

$$\left(1 - \frac{\underline{22}}{100}\right) \times \left(.44 \times \underline{161} + .32 \times \underline{163} + .28 \times (100 - \underline{161} - \underline{163})\right) + .18 \times \underline{22}$$

MW_{fg} = molecular weight of flue gas

MW_i = molecular weight of component

C_i = mole fraction of each component

172 Gas temperature economizer inlet (°F)

Same as $\underline{158}$

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173 **Gas flow rate original estimate (lb/hr)**

$$\dot{m} = \frac{MP\dot{V}}{RT}$$

$.155 \times \underline{171} \times \underline{32}$

By ideal gas law--using measured flow rate. Estimate not used in other calculations.

174 **Economizer inlet water temperature (°F)**

Average of 30 minute readings from boiler control panel.

175 **Economizer outlet water temperature (°F)**

Average of 30 minute readings from boiler control panel.

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176	Enthalpy of feedwater (Btu/lb)	-------	
	-------		From ASME Steam Tables, copyright 1967. Saturated liquid at economizer inlet temperature.
177	Steam enthalpy (Btu/lb)	-------	
	-------		From ASME Steam Tables, copyright 1967. Superheated properties delivered temperature and pressure.
178	Gas temperature screen tubes (°F)	-------	
	Same as 156	-------	

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179 Wind box pressure (inches H_2O)

Average of 30 minute readings from boiler control panel.

180 Enthalpy gain (Btu/lb)

$\Delta h = h_s - h_i$

177 - 176

Δh = enthalpy gain (Btu/lb)

h_s = steam outlet enthalpy (Btu/lb)

h_i = feedwater enthalpy (Btu/lb)

181 Date (mo/day)

182
183
184
185 Fusion temperatures (°F) -------

------- Laboratory measured fusion temperatures of coal/dRDF blend samples from daily composites.

THE FOLLOWING COLUMNS ARE MINERAL ANALYSIS ON A SAMPLE TYPE BASIS

187 Sample type

Blend = mixture of coal/dRDF

Coal = coal used on date of sample

Bottom ash = bottom ash sample

ESP ash = fly ash collected by ESP

Mult. = fly ash collected by the multiclone dust collector

B.O. ash = fly ash sampled at the boiler outlet upstream of the multiclone dust collector

188 Date (mo/day) -------

------- Date composite sample was collected.

189 194
190 195
191 196 Mineral analysis (%) -------
192 197
193 198

------- From standard solid fuel laboratory mineral analysis.

199
200 Ash type index -------

$$\frac{193 + 194}{190}$$

200 > 1 ash is lignitic

200 < 1 ash is bituminous

THE FOLLOWING COLUMNS ARE ON AN EFFICIENCY TEST PERIOD BASIS

201 Date
(mo/day/test number) -------

------- Test number corresponds to fuel bunker filling.

202 Time -------

------- Time of initiation of filling of empty bunker.

203 Coal input as received (lb/hr)

$$W_{CA-R} = \left[CF5(NO5) - CF3(NO3) \right] \frac{2000}{\Delta t}$$

W_{CA-R} = weight of coal as received (lb/hr)

CF5 = Scale 5 correction factor (1.144)

NO5 = Scale 5 reading (ton)

CF3 = Scale 3 correction factor (1.036)

NO3 = Scale 3 reading (ton)

Δt = elapsed time between bunker fillings (hr)

204 Pellet input as received (lb/hr)

$$W_{RA-R} = \frac{2000}{\Delta t}\ CF3(NO3)$$

W_{RA-R} = weight of dRDF as received (lb/hr)

CF3 = Scale 3 correction factor (1.036)

NO3 = Scale 3 readings (ton)

Δt = elapsed time between bunker fillings (hr)

205 Coal moisture (%)

$$m_{fC} = \frac{W_{mc}(100)}{W_{CAR}}$$

----

m_{fC} = coal moisture (%)

W_{mC} = weight of moisture in coal (lb)

W_{CA-R} = weight of coal as received (lb)

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206 Pellet moisture (%)

$$m_{fR} = \frac{W_{mC}\ (100)}{W_{CA-R}}$$

----

m_{fR} = moisture in dRDF sample (%)

W_{mD} = weight of moisture in sample (lb)

W_{CA-R} = weight of as received sample (lb)

207 Coal input dry basis (lb/hr)

$$W_C = \left(\frac{1 - m_{fc}}{100}\right)\left(W_{CA-R}\right)$$

$$\left(\frac{100\ -\ \underline{205}}{100}\right) \times \underline{203}$$

W_C = weight of coal dry basis (lb/hr)

m_{fC} = coal moisture (%)

W_{CA-R} = weight of coal as received (lb/hr)

208 Pellet input dry basis (lb/hr)

$$W_R = \left(1 - \frac{m_{fR}}{100}\right)\left(W_{RA-R}\right)$$

$$\left(\frac{100 - \underline{206}}{100}\right) \times \underline{204}$$

W_R = weight of dRDF dry basis (lb/hr)

m_{fR} = dRDF moisture (%)

W_{RA-R} = weight of dRDF as received (lb/hr)

209 Carbon input (lb/hr)

$$W_{carbon} = \frac{W_C C_C + W_R C_R}{100}$$

$$\frac{\underline{207}}{100} \times \underline{88} + \frac{\underline{208}}{100} \times \underline{108}$$

W_{carbon} = carbon input rate (lb/hr)

W_C = dry coal input rate (lb/hr)

C_C = average carbon content of coal type (%)

W_R = dry dRDF input rate (lb/hr)

C_R = average carbon content of pellet type (%)

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210 Hydrogen input (lb/hr)

$$W_H = \frac{W_C H_C + W_R H_R}{100}$$

$$\frac{\underline{207}}{100} \times \underline{87} + \frac{\underline{208}}{100} \times \underline{107}$$

W_H = hydrogen input rate (lb/hr)

W_C = dry coal input rate (lb/hr)

H_C = average hydrogen content of coal type (%)

W_R = dry dRDF input rate (lb/hr)

H_R = average hydrogen content of dRDF type (%)

211 Sulfur input (lb/hr)

$$W_S = \frac{W_C S_C + W_R S_R}{100}$$

$$\frac{\underline{207}}{100} \times \underline{90} + \frac{\underline{208}}{100} \times \underline{110}$$

W_S = sulfur input rate (lb/hr)

W_C = dry coal input rate (lb/hr)

S_C = average sulfur content of coal type (%)

W_R = dry dRDF input rate (lb/hr)

S_R = average sulfur content of dRDF type (%)

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212 Oxygen input (lb/hr)

$$W_O = \frac{W_C O_C + W_R O_R}{100}$$

$$\frac{\underline{207}}{100} \times \underline{92} + \frac{\underline{208}}{100} \times \underline{112}$$

W_O = oxygen input rate (lb/hr)

W_C = dry coal input rate (lb/hr)

O_C = average oxygen content of coal type (%)

W_R = dry dRDF input rate (lb/hr)

O_R = average oxygen content of pellet type (%)

213 Fuel nitrogen input (lb/hr)

$$W_N = \frac{W_C N_C + W_R N_R}{100}$$

$$\frac{\underline{207}}{100} \times \underline{89} + \frac{\underline{208}}{100} \times \underline{109}$$

W_N = nitrogen in fuel input rate (lb/hr)

W_C = dry coal input rate (lb/hr)

N_C = average nitrogen content of coal type (%)

W_R = dry dRDF input rate (lb/hr)

N_R = average nitrogen content of dRDF type (%)

214 Ash input
(lb/hr)

$$W_I = \frac{W_C I_C + W_R I_R}{100}$$

$$\frac{\underline{207}}{100} \times \underline{86} + \frac{\underline{208}}{100} \times \underline{106}$$

W_I = inert input rate (lb/hr)

W_C = dry coal input rate (lb/hr)

H_C = average inerts content of coal type (%)

W_R = dry dRDF input rate (lb/hr)

I_R = average inerts content of dRDF type (%)

215 Heat input rate
(10^6 Btu/hr)

$$E_i = \frac{\left(W_C HHV_C + W_R HHV_R \right)}{10^6}$$

$$\frac{\underline{207} \times \underline{95} + \underline{208} \times \underline{115}}{10^{6}}$$

E_i = fuel energy input (10^6 Btu/hr)

W_C = dry coal input rate (lb/hr)

HHV_C = coal higher heating value (Btu/lb)

W_R = dry dRDF input rate (lb/hr)

HHV_R = dRDF higher heating value (Btu/lb)

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216 Moisture input rate (lb/hr)

$$W_{WE} = W_{CA-R} + W_{RA-R} - W_C - W_R$$

$\underline{203} + \underline{204} - \underline{207} - \underline{208}$

W_{WE} = weight of moisture input (lb/hr)

W_{CA-R} = as received coal input rate (lb/hr)

W_{RA-R} = as received dRDF input rate (lb/hr)

W_C = dry coal input rate (lb/hr)

W_R = dry dRDF input rate (lb/hr)

217 dRDF substitution by weight (%)

$$\frac{W_{RA-R} \times 100}{W_{RA-R} + W_{CA-R}}$$

$$\frac{\underline{204} \times 100}{\underline{203} + \underline{204}}$$

W_{RA-R} = as-received dRDF input rate (lb/hr)

W_{CA-R} = as-received coal input rate (lb/hr)

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218 dRDF heat substitution rate
(%)

$$\gamma = \frac{100 W_R \; HHV_R}{W_R \; HHV_R + W_C \; HHV_C}$$

$$\frac{\underline{208} \times \underline{115} \times 100}{\underline{208} \times \underline{115} + \underline{207} \times \underline{95}}$$

γ = dRDF heat substitution (%)

W_R = dry dRDF input rate (lb/hr)

HHV_R = dRDF higher heating value (Btu/lb)

W_C = dry coal input rate (lb/hr)

HHV_C = coal higher heating value (Btu/lb)

219 Unburnt carbon in bottom ash
(lb/hr)

$$UC_{BA} = \frac{W_{BA} \; U_{CBA}}{100}$$

$$\underline{236} \times \frac{\underline{70}}{100}$$

UC_{BA} = unburnt carbon in bottom ash (lb/hr)

W_{BA} = bottom ash output rate (lb/hr)

U_{CBA} = unburnt combustibles in bottom ash (%)

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220 Unburnt carbon in fly ash (lb/hr)

$$UC_{FA} = \frac{W_{FA}\ U_{CFA}}{100}$$

$\underline{237} \times \frac{80}{100}$

UC_{FA} = unburnt carbon in fly ash (lb/hr)

W_{FA} = fly ash output rate (lb/hr)

U_{CFA} = unburnt combustibles in fly ash (%)

221 Efficiency test number -------

Same as 201 -------

222 Start time (--) -------

Same as 202 -------

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223	End time (--)	-------
	222 previous	Start time of next test
224	Δt (hr)	Time end - time start
	223 - 222	Elapsed time of efficiency test
225	Fuel usage dry basis (lb/hr)	$W_f = W_C + W_R$
	207 + 208	W_f = total fuel weight on dry basis (lb/hr) W_C = dry coal weight (lb/hr) W_R = dry dRDF weight (lb/hr)

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226 Heat input (10^6 Btu/hr)

Same as 215

----

227 Feedwater input (10^3 lb/hr)

$W_{FW} = (FIF - FIS) \times 1.750$

W_{FW} = weight of feedwater input (10^3 lb/hr)

FIF = feedwater integrator finish (--)

FIS = feedwater integrator start (--)

1.750 = integrator multiplier

228 Feedwater input minus blowdown (10^3 lb/hr)

$W_{SO} = (1 - .025)\ W_{FW}$

.975 × 227

W_{SO} = steam output (10^3 lb/hr)

W_{FW} = feedwater input (2.5 percent blowdown)

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229 Steam output by integrator (10^3 lb)

$$W_S = (SIF - SIS) \times 1.750 \times .957$$

SIF = steam integrator finish reading

SIS = steam integrator start reading

1.750 = integrator readout multiplier

.957 = steam integrator calibration factor

230 Steam generation rate (10^3 lb/hr)

$$W_{SE} = \frac{W_S}{\Delta t}$$

$\frac{228}{224}$

W_{SE} = steam generation rate

W_S = total steam generated

Δt = elapsed time of test

231 Steam enthalpy gain (Btu/lb)

Same as 180

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232 Measured steam heat output (10^6 Btu/hr)

$$Q_o = W_{SE}\ \Delta h$$

$$\frac{\underline{230} \times \underline{231}}{1000}$$

Q_o = steam heat output (10^6 Btu/hr)

W_{SE} = steam generation rate (10^3 lb/hr)

Δh = steam enthalpy gain (10^3 Btu/lb)

233 Stoichiometric air requirement (lb/lb)

$$A\theta = 11.51C + 34.3\left(H - \frac{O}{8}\right) + 4.335S$$

$$\left(11.51 \times \frac{\underline{209}}{\underline{225}}\right) +$$

$$34.3 \times \left(\frac{\underline{210}}{225} - \frac{\underline{212}}{8 \times \underline{225}}\right) +$$

$$4.335 \times \left(\frac{\underline{211}}{\underline{225}}\right)$$

$A\theta$ = theoretical air (lb/lb)

C = carbon content of fuel

H = hydrogen content of fuel

O = oxygen content of fuel

S = sulfur content of fuel

234 Excess air (%) -------

Same as **148** -------

235 Air flow into boiler (10^3 lb/hr)

$$A_t = W_f A\theta' \left(1 + \frac{EA}{100}\right)$$

$$\underline{225} \times \underline{233} \times \left(\frac{100 + \underline{234}}{100}\right)$$

A_t = total air flow (lb/hr)

W_f = dry fuel input rate (lb/hr)

$A\theta'$ = theoretical A:F ratio (lb/lb)

EA = excess air (%)

236 Bottom ash output (lb/hr)

$$BA = \frac{W_I - W_P + UC_{FA}}{1 - \frac{U_C}{100}}$$

$$\frac{\underline{238} - \underline{237} + \underline{220}}{1 - \frac{\underline{70}}{100}}$$

BA = bottom ash output (lb/hr)

W_I = inerts input rate (lb/hr)

W_P = particulate rate ESP inlet (lb/hr)

UC_{FC} = fly ash unburnt carbon (lb/hr)

U_C = bottom ash unburnt carbon (%)

237 Fly ash output (lb/hr)

$$FA = E_pE_i$$

$$\underline{17} \times \underline{226}$$

FA = fly ash output (lb/hr)

E_p = fly ash emission (lb/10^6 Btu)

E_i = heat input (10^6 Btu/hr)

238 Total inerts input (lb/hr) -------

Same as **214** -------

239 R/C energy percent (%) -------

------- From ABMA Standard Radiation Loss Chart (loss as percent of input heat)

240 R/C energy losses (10^6 Btu/hr) $L\beta = R/C \; E_i$

$\underline{226} \times \frac{\underline{239}}{100}$

$L\beta$ = radiation/convection losses (10^6 Btu/hr)

R/C = loss rate (%)

E_i = energy input (10^6 Btu/hr)

241 Input-output efficiency (%)

$$\eta_{I-O} = \frac{100Q_o}{E_i}$$

$$\frac{\underline{232} \times 100}{\underline{226}}$$

η_{I-O} = input-output efficiency (%)

Q_o = measured steam output (10^6 Btu/hr)

E_i = energy input (10^6 Btu/hr)

242 Boiler load (%)

$$\ell = \frac{100\ Q_o}{150\ (1200)\ 10^{-3}}$$

$$\frac{\underline{232} \times 100}{180}$$

ℓ = boiler load (% capacity)

Q_o = energy output as steam (10^6 Btu/hr)

243 Bottom ash heat loss
(10^6 Btu/hr)

$$L_{uc} = \frac{UC_{BA} \times HHV_{carbon}}{10^6}$$

$$\frac{\underline{219} \times 14100}{10^6}$$

L_{uc} = unburnt carbon heat loss (10^6 Btu/hr)

UC_{BA} = bottom ash unburnt carbon (lb/hr)

HHV_{carbon} = 14100 Btu/lb

244 Fly ash heat loss
(10^6 Btu/hr)

$$L_{FA} = \frac{UC_{FA}\ HHV_{carbon}}{10^6}$$

$$\frac{\underline{220} \times 14100}{10^6}$$

L_{FA} = fly ash heat loss (10^6 Btu/hr)

UC_{FA} = fly ash unburnt carbon (lb/hr)

HHV_{carbon} = carbon higher heating value (14100 Btu/lb)

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245 CO_2 output rate (lb/hr)

$$W_{CO_2} = \frac{44}{12}\left(W_{carbon} - UC_{BA} - UC_{FA}\right)$$

3.667 × 209 - 219 - 220

W_{CO_2} = CO_2 output rate (lb/hr)

W_{carbon} = carbon input rate (lb/hr)

UC_{BA} = bottom ash unburnt carbon (lb/hr)

UC_{FA} = fly ash unburnt carbon (lb/hr)

246 H_2O output rate (lb/hr)

$$W_{H_2O} = W_{WE} + 9\ W_H$$

---

216 + (9 × 210)

W_{H_2O} = H_2O output rate (lb/hr)

W_{WE} = fuel moisture inputs (lb/hr)

W_H = hydrogen input (lb/hr)

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247 SO_2 output rate (lb/hr)

$$W_{SO_2} = 2\ W_S$$

---

2 × 211

W_{SO_2} = SO_2 output rate (lb/hr)

W_S = sulfur input rate (lb/hr)

248 O_2 output rate (lb/hr)

$$W_{O_2} = .233\ A_t + W_o - .727\ W_{CO_2} - 8\ W_H - W_S$$

(.233 × 235 × 1000) + 212 -

(.727 × 245) -

(8 × 210) - 211

W_{O_2} = O_2 output rate (lb/hr)

A_t = total air input (lb/hr)

W_o = oxygen input with fuel (lb/hr)

W_{CO_2} = CO_2 output (lb/hr)

W_H = hydrogen in fuel input (lb/hr)

W_S = sulfur in fuel input (lb/hr)

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249 N_2 output rate (lb/hr)

$$W_{N_2} = .767\ A_t + W_N$$

---

767 × 235 + 213

W_{N_2} = N_2 output rate (lb/hr)

A_t = total air input (lb/hr)

W_N = nitrogen input in fuel (lb/hr)

250 Temperature economizer outlet (°F)

As final heat exchanger outlet temp. Average of 30 minute reading during efficiency test as printed on continuous recorder calibrater vapor pressure thermometer.

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251 Total dry flue gas rate (10^3 lb/hr)

$$DFG = W_{CO_2} + W_{SO_2} + W_{O_2} + W_{N_2}$$

$$\frac{\underline{245} + \underline{247} + \underline{248} + \underline{249}}{10^3}$$

DFG = dry flue gas output (lb/hr)

W_{CO_2} = weight of CO_2 output (lb/hr)

W_{SO_2} = SO_2 output rate (lb/hr)

WO_2 = oxygen output rate (lb/hr)

WN_2 = nitrogen outpute rate (lb/hr

252 Dry flue gas sensible heat loss (10^6 Btu/hr)

$$L_G = m\ Cp\Delta T$$

$$\frac{(\underline{250} - 70) \times \underline{251} \times .2423}{10^3}$$

L_G = dry flue gas heat loss (Btu/hr)

m = mass flow rate of dry flue gas (lb/hr)

Cp = average specific heat of dry flue gas (Btu/lb °F)

ΔT = Temperature of flue gas above 70°F reference

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253 Enthalpy of wet flue gas (Btu/lb) -------

According to ASME-PTC 4.1. Enthalpy of moisture in flue gas measured at economizer outlet temperature and 1 psia. Superheated. From 1967 ASME Steam Tables.

254 Wet flue gas loss (10^6 Btu/hr)

$$L_{Wfg} = W_{H_2O} \left(h_{go} - h_1\right)$$

$(\underline{253} - 38) \times \underline{246} \times 10^{-6}$

L_{Wfg} = loss due to moisture in flue gas (10^6 Btu/hr)

W_{H_2O} = moisture output rate (lb/hr)

h_{go} = enthalpy of superheated water vapor in flue gas (Btu/lb)

h_1 = enthalpy of liquid water at 70°F (Btu/lb)

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255 Loss in multiclone rejects unburnt carbon (10^6 Btu/hr)

$$L_{MUC} = m_{MFA}\ UC_{MFA}\ HHV_{carbon}$$

L_{MUC} = loss of unburnt carbon in multiclone collect not reinjected

m_{MFA} = multiclone collect rate (lb/hr)

UC_{MFA} = unburnt carbon in multiclone collect (%/100)

HHV_{carbon} = 14100 Btu/lb

256 Calculated boiler outlet H_2O (% vol)

$$H_2O = \frac{18W_{H_2O}}{29.5\left(W_{H_2O} + DFG\right)}$$

$$\frac{100 \times \underline{246}}{\underline{246} + (610 + \underline{251})}$$

H_2O = moisture concentration (percent by volume)

18 = molecular weight of H_2O

29.5 = average molecular weight of flue gas

W_{H_2O} = flue gas moisture rate (lb/hr)

DFG = dry flue gas rate (lb/hr)

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257 Total losses
(10^6 Btu/hr)

$$L_T = L_\beta + L_{UC} + L_{FA} + L_G + L_{WFG} + L_{MUC}$$

240 + 243 + 244 + 252 + 254 + 255

L_T = total losses (10^6 Btu/hr)

Other L's: see 240 through 255

258 Efficiency by heat balance
(%)

$$\eta = \left(1 - \frac{L_T}{E_i}\ 100\right)$$

$$\left(1 - \frac{257}{226} \times 100\right)$$

η = heat balance efficiency (%)

L_T = total losses (10^6 Btu/hr)

E_i = total energy input (10^6 Btu/hr)

261 Test No.
(mo/day/year)

------- -------

262 Heat input
(10^6 Btu/hr)

Same as 215

----

263 R/C loss
(%)

$$E_{R/C} = \frac{L_\beta}{E_i} \times 100$$

Same as 239

$E_{R/C}$ = percent of input energy lost to radiative/convective losses (%)

L_β = R/C losses (10^6 Btu/hr)

E_i = input energy (10^6 Btu/hr)

264 Bottom ash loss
(%)

$$E_{UC} = \frac{L_{UC}}{E_i} \times 100$$

$$100 \times \frac{243}{262}$$

E_{UC} = bottom ash combustible losses (%)

L_{UC} = bottom ash combustibles losses (10^6 Btu/hr)

E_i = energy input (10^6 Btu/hr)

265 Fly ash losses (%)

$$E_{FA} = \frac{L_{FA}}{E_i} \times 100$$

$$100 \times \frac{\underline{244}}{\underline{262}}$$

E_{FA} = percent of input lost in fly ash (%)

L_{FA} = fly ash losses (10^6 Btu/hr)

E_i = energy input (10^6 Btu/hr)

266 Dry flue gas loss (%)

$$E_G = \frac{L_G}{E_i} \times 100$$

$$100 \times \frac{\underline{252}}{\underline{262}}$$

E_G = dry flue gas loss percent of input (%)

L_G = dry flue gas losses (10^6 Btu/hr)

E_i = energy input (10^6 Btu/hr)

267 Wet flue gas loss (%)

$$E_{WFG} = \frac{L_{WFG}}{E_i}$$

$$100 \times \frac{\underline{254}}{\underline{262}}$$

E_{WFG} = percent of input loss to evaporated moisture in flue gas (%)

L_{WFG} = moisture flue gas losses (10^6 Btu/hr)

E_i = energy input (10^6 Btu/hr)

268 Total loss (%)

$$E_{Loss} = \frac{L_T}{E_i} \times 100$$

$$100 \times \frac{\underline{257}}{\underline{262}}$$

E_{Loss} = percent of input energy lost (%)

L_T = total of losses (10^6 Btu/hr)

E_i = energy input (10^6 Btu/hr)

269 Efficiency (%)

Same as 258

----

270 Inert input rate ($lb/10^6$ Btu)

$$A_I = \frac{W_I}{E_1}$$

214

215

A_I = ash input rate ($lb/10^6$ Btu)

W_I = inert input rate (lb/hr)

E_1 = heat input rate (10^6 Btu/hr)

271 Sulfur input rate ($lb/10^6$ Btu)

$$A_S = \frac{W_S}{E_1}$$

211

215

A_S = sulfur input rate ($lb/10^6$ Btu)

W_S = sulfur input rate (lb/hr)

E_1 = heat input rate (10^6 Btu/hr)

272 Nitrogen in fuel input rate ($lb/10^6$ Btu)

$$A_N = \frac{W_N}{E_i}$$

$$\frac{\underline{213}}{\underline{215}}$$

A_N = nitrogen input ($lb/10^6$ Btu)

W_N = nitrogen fuel input rate (lb/hr)

E_i = heat input rate (10^6 Btu/hr)

273 Chlorine input rate ($lb/10^6$ Btu)

$$A_{Cl} = \frac{W_{Cl}}{E_i}$$

$$\frac{\underline{207} \times \underline{91} + \underline{208} \times \underline{111}}{(\underline{207} + \underline{208}) \times \underline{215}}$$

A_{Cl} = chlorine input rate ($lb/10^6$ Btu)

W_{Cl} = chlorine input (lb/hr)

E_i = heat input rate (10^6 Btu/hr)

COAL
INDUCED DRAFT VOLUME ANALYSIS

Inputs

Fuel

	(lb/lb as-fired fuel)	O_2 required (lb)
Moisture	.070	---
Hydrogen	.045	.360
Carbon	.656	1.749
Sulfur	.031	.031
Oxygen	.062	-.062
		2.078

Air (excess air 50 percent)

O_2	3.117
N_2	10.181

Outputs

Flue gas

H_2O	.475	÷	18	=	.0264
CO_2	2.405	÷	44	=	.0546
N_2	10.181	÷	28	=	.3636
SO_2	.062	÷	64	=	.0010
O_2	1.039	÷	32	=	.0325
	14.162				0.4781 moles

The universal gas law, $PV = nRT$, requires that at 450°F and 1 atm. pressure,

$$V = 664n$$

Therefore,

$$V = 664\ (.4781) = 317\ \text{ft}^3/\text{lb fuel}$$

$$V = \frac{317 \times 1 \times 10^6}{11{,}805\ \frac{\text{Btu}}{\text{lb}^*}} = 26{,}892\ \frac{\text{ft}^3}{10^6\ \text{Btu}}$$

* on an as-received basis

TELEDYNE dRDF
INDUCED DRAFT VOLUME ANALYSIS

Inputs

Fuel	(lb/lb as-fired fuel)	O_2 required
Moisture	.337	---
Hydrogen	.041	.328
Carbon	.304	.811
Sulfur	.004	.004
Oxygen	.218	-.218
		.925

Air excess air 50 percent

O_2	1.387
N_2	4.532

Outputs

Flue gas		
H_2O	0.706 ÷ 18 =	.0392
CO_2	1.115 ÷ 44 =	.0253
N_2	4.532 ÷ 28 =	.1619
SO_2	0.008 ÷ 64 =	.0001
O_2	0.462 ÷ 32 =	.0144
	6.823	.2410 moles

The universal gas law, $PV = nRT$, requires that at 450°F and 1 atm. pressure,

$$V = 664n$$

Therefore,

$$V = 664\ (.2410) = 160\ ft^3/lb\ fuel$$

$$V = \frac{160 \times 1 \times 10^6}{5,385\ \frac{Btu}{lb^*}} = 29,717\ \frac{ft^3}{10^6\ Btu}$$

* on as as-received basis

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Cp CALCULATION

Date 3/7/79 Coal 86 percent excess air

@ 410°F → 70°F

CO_2 37,298 lb/hr = 847 moles/hr
O_2 29,866 lb/hr = 933 moles/hr
N_2 206,032 lb/hr = 7,354 moles/hr
SO_2 1,190 lb/hr = negligible

Per hour then:

N_2 $h_i = 3{,}680.8$ $h_o = 6{,}056.4$ $\Delta h = 2{,}375.6 \times 7{,}354 = 17.470 \times 10^6$ Btu

O_2 $h_i = 3{,}676.1$ $h_o = 6{,}115.7$ $\Delta h = 2{,}439.6 \times 933 = 2.276 \times 10^6$ Btu

CO_2 $h_i = 3{,}968.3$ $h_o = 7{,}279.8$ $\Delta h = 3{,}311.5 \times 847 = 2.805 \times 10^6$ Btu

$$\Sigma \Delta h = Cp \ \Delta t \ S\overline{M}$$

$$\frac{22.551 \ \frac{\text{MMBtu}}{\text{hr}}}{274{,}400 \ (410-70)} = .2417 = Cp$$

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Cp CALCULATION

Date 3/14/79 1:2 NCRR 90 percent excess air

@ 430°F

N_2 189,365 lb/28.016 = 6,759 moles/hr
O_2 28,418 lb/32.00 = 888 moles/hr
CO_2 33,092 lb/44.01 = 752 moles/hr

Per hour then:

N_2 $h_i = 3,680.8$
$h_o = 6,197.5$ $\Delta h = 2,516.7 \times 6,759 = 17.010 \times 10^6$ Btu

O_2 $h_i = 3,676.1$
$h_o = 6,263.7$ $\Delta h = 2,587.6 \times 888 = 2.298 \times 10^6$ Btu

CO_2 $h_i = 3,968.3$
$h_o = 7,491.3$ $\Delta h = 3,523.0 \times 752 = 2.649 \times 10^6$ Btu

$\Sigma \Delta h = Cp\ \Delta t\ S\overline{M}$

$$\frac{21.957 \text{ MMBtu}}{252,600\ (430-70)} = .2414 = Cp$$

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Cp CALCULATION

Date 4/19/79 1:2 Teledyne 55 percent excess air

To 440°F

N_2 245,000/28.016 = 8,745 moles/hr
O_2 37,335/32.00 = 1,166 moles/hr
CO_2 43,141/44.01 = 980 moles/hr

Per hour then:

N_2 $h_i = 3,680.8$, $h_o = 6,268.1$ $\Delta h = 2,587.3 \times 8,745 = 22.626 \times 10^6$ Btu

O_2 $h_i = 3,676.1$, $h_o = 6,337.9$ $\Delta h = 2,661.8 \times 1,166 = 3.104 \times 10^6$ Btu

CO_2 $h_i = 3,968.3$, $h_o = 7,597.6$ $\Delta h = 3,629.3 \times 980 = 3.557 \times 10^6$ Btu

$$\Sigma\Delta h = Cp\ \Delta t\ S\overline{M}$$

$$\frac{29.287\ \text{MMBtu}}{326,052\ (440-70)} = .2427 = Cp$$

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Cp CALCULATION

Date 5/10/79 1:1 Teledyne 84 percent excess air

at 440°F

N_2 283,732/28.016 = 10,127 moles/hr
O_2 49,352/32.00 = 1,542 moles/hr
CO_2 44,235/44.01 = 1,005 moles/hr

Per hour then:

N_2 $h_i = 3{,}680.8$, $h_o = 6{,}268.1$ $\Delta h = 2{,}587.3 \times 10{,}127 = 26.202 \times 10^6$ Btu

O_2 $h_i = 3{,}676.1$, $h_o = 6{,}337.9$ $\Delta h = 2{,}661.8 \times 1{,}542 = 4.104 \times 10^6$ Btu

CO_2 $h_i = 3{,}968.3$, $h_o = 7{,}597.6$ $\Delta h = 3{,}629.3 \times 1{,}005 = 3.647 \times 10^6$ Btu

$$\Sigma\Delta h = Cp\ \Delta t\ \overline{SM}$$

$$\frac{33.953 \text{ MMBtu}}{377{,}772\ (440-70)} = .2429 = Cp$$

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Cp CALCULATION

Date 5/17/79 Coal 49 percent excess air

at 445°F

N_2 222,121/28.016 = 7,928 moles/hr
O_2 26,139/32.00 = 817 moles/hr
CO_2 48,895/44.01 = 1,111 moles/hr

Per hour then:

N_2 $h_i = 3,680.8$, $h_o = 6,303.5$ $\Delta h = 2,622.7 \times 7,928 = 20.793 \times 10^6$ Btu

O_2 $h_i = 3,676.1$, $h_o = 6,375.1$ $\Delta h = 2,699 \times 817 = 2.205 \times 10^6$ Btu

CO_2 $h_i = 3,968.3$, $h_o = 7,650.9$ $\Delta h = 3,682.6 \times 1,111 = 4.091 \times 10^6$ Btu

$$\Sigma \Delta h = Cp \, \Delta t \, S\overline{M}$$

$$\frac{27.089 \text{ MMBtu}}{297,698\ (445-70)} = .2426 = Cp$$

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CONVERSION

ppm to lb/ft^3

$$pV = nRT$$

$$n = \frac{m}{M}$$

$R = .7302$ atm $ft^3/mole_{lb}$ °K

let ppm be partial pressure, need

$$\frac{m}{V} = \frac{nM}{V} \qquad \frac{n}{V} = \frac{p}{RT}$$

$$\frac{nM}{V} = \frac{pM}{RT} = \frac{ppm \times 10^{-6}\ M}{.7302\ (530)}$$

for SO_2 $M = 64$

$$\frac{lb}{ft^3} = .1654 \times 10^{-6}\ ppm$$

for NO_2 $M = 46$

$$\frac{lb}{ft^3} = .1189 \times 10^{-6}\ ppm$$

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CONVERSION (continued)

ppm to lb/ft^3

for CO $M = 28$

$$\frac{lb}{ft^3} = .7235 \times 10^{-7}\ ppm$$

for CL^- $M = 34$

$$\frac{lb}{ft^3} = .8785 \times 10^{-7}\ ppm$$

for F^- $M = 18$

$$\frac{lb}{ft^3} = .4651 \times 10^{-7}\ ppm$$

dRDF TEST, G.E. PLANT, ERIE, PENNSYLVANIA

Pellets received

NCRR - 35 loads	546 tons
Teledyne - 57 loads	1,191 tons

Pellets burned

NCRR (Belt Scale #3)	492 tons
Teledyne (Belt Scale #3)	1,256 tons

Dry weight

Teledyne received at 15.6 percent moisture (average of 4 samples)

$1,191 \times (1 - .156) = 1,055$ dry tons

Teledyne as burned, average 26.0 percent moisture

$1,256 \times (1 - .26) = 928$ dry tons

Pellets remaining at end of test

$\frac{(1,005 - 928)}{(1 - .157)} = 91$ tons

APPENDIX D

EVALUATION OF dRDF/COAL FUEL AND ASH DEPOSITS

EVALUATION OF dRDF/COAL FUEL AND ASH DEPOSITS

FUELS AND ASH DEPOSIT SAMPLES BASED ON FUEL AND ASH DEPOSIT SAMPLES IN A TEST BURN ON A SPREADER STOKER STEAM GENERATOR

Prepared by

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Prepared for

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Xenia, Ohio 45385

April 1980

FWDC No. 9-41-5563

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INTRODUCTION

The potential for fouling and tube wastage while firing densified refuse-derived fuel (dRDF) with coal in a steam generator was evaluated by analyzing the raw coal, the Teledyne dRDF pellets, and a blended coal/dRDF fuel. We also evaluated the fireside deposits formed after trial or test burns of the raw coal and blended fuel in a General Electric Company steam generator at Erie, Pennsylvania. Simple crucible corrosion tests, using portions of furnace ash deposit, were performed at 500, 750, and 950°F for 100 hours as a qualitative means of evaluating tube wastage.

FUEL ANALYSIS

Proximate analysis, ultimate analysis, heating value, ash-fusion temperatures, and ash chemistry were performed on the coal, Teledyne dRDF pellets, and blended coal/dRDF fuels. The data are reported in Tables 1 and 2.

The ash fusion temperatures and ash chemistry for the coal, Teledyne dRDF pellets, and blended fuel appears in Table 2. Since all fireside problems (i.e., deposit formation and tube wastage) depend on the presence of a molten phase, the potential for a fuel to cause fireside problems must be evaluated in terms of the potential for forming molten constituents among the impurities found in the fuel. Therefore, evaluation of the melting temperture of the ash in terms of its chemistry is important. An understanding of this relationship makes possible the estimation of the fusion temperatures of a blend from the ash chemistry of the component fuels. Such an estimate can only be made, however, if the impurities behave as a composite or homogeneous mass at the heat

Table 1 Fuel Analysis

Item	% by Weight					
	Coal A		Teledyne dRDF		Teledyne dRDF/ Coal D Blend	
	As Received	Dry	As Received	Dry	As Received	Dry
Sample Description:	Composite from 3/5-9		Composite from 5/9-11		Composite from 5/7-11	
Fixed Carbon	49.74	51.01	12.89	14.66	34.83	36.82
Volatile Matter	32.65	33.48	62.50	71.07	48.51	51.28
Ash	15.12	15.51	12.55	14.27	11.26	11.90
Moisture	2.49	---	12.06	---	5.40	---
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
Carbon	66.87	68.58	33.68	43.98	55.16	58.31
Hydrogen	5.24	5.38	4.47	5.08	5.31	5.61
Oxygen	5.31	5.43	31.19	35.47	21.00	22.21
Nitrogen	0.85	0.87	0.43	0.49	0.69	0.73
Sulfur	3.93	4.03	0.36	0.41	0.95	1.00
Ash	15.12	15.51	12.55	14.27	11.26	11.90
Chlorine	0.19	0.20	0.26	0.30	0.23	0.24
Moisture	2.49	---	12.06	---	5.40	---
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
HHV, Btu/lb	11,956	12,261	6,818	7,753	9,917	10,483

Table 2 Ash Chemistry of the Fuels

Elemental Oxide	% by Weight		
	Coal A	Teledyne dRDF	Teledyne dRDF/ Coal D Blend
SiO_2	35.2	46.7	42.9
Al_2O_3	17.5	14.4	17.9
TiO_2	0.8	1.7	1.3
Fe_2O_3	33.2	6.0	11.9
CaO	7.2	10.6	11.3
MgO	0.4	0.9	0.6
Na_2O	0.3	5.6	3.5
K_2O	1.9	1.3	1.3
ZnO	0.06	0.3	0.2
P_2O_5	0.1	0.7	0.5
MnO_2	0.03	0.1	0.06
NiO	0.04	0.02	0.04
Cl	0.06	0.1	0.1
SO_3	2.1	2.6	4.9
CuO	0.06	0.06	0.1
PbO	0.08	0.25	0.19
TOTAL	99.03	91.86	90.19

Table 2 Ash Chemistry of the Fuels (Cont)

Ash Fusion Temperature (°F)	Coal A		Teledyne dRDF		Teledyne dRDF/ Coal D Blend	
	Reducing	Oxidizing	Reducing	Oxidizing	Reducing	Oxidizing
Initial Deformation	2060	2140	2100	2180	2160	2340
Softening (Sph.)	2100	2560	2160	2210	2280	2400
Softening (Hem.)	2160	2580	2180	2240	2300	2420
Fluid	2200	2620	2200	2380	2320	2470

exchanger surface. A knowledge of the relationship between the fusion temperatures and the chemistry also provides a better understanding of which impurity contributes to low melting temperatures in the ash deposited.

Deposits can be formed by the freezing and sticking of mixtures of dry or molten particles or both when they impact on cool heat-transfer surfaces. The major impurities found in coal ash (e.g., Al_2O_3, SiO_2, Fe_2O_3, MgO, and CaO) generally form deposits in this manner. The minor constituents (e.g., sodium and potassium found in coal and zinc and lead found in refuse) volatilize during combustion and condense on the cool tube surfaces as either a molten or solid sulfate or chloride.

Corrosion in steam generators firing coal has been attributed to the deposition of molten pyrosulfates and alkali trisulfates. In the temperature range from 550 to 900°F, corrosion might be attributed to the pyrosulfates $Na_2S_2O_7$ and $K_2S_2O_7$. The formation of the pyrosulfates depends on the existence of a reducing environment and the presence of at least 150 ppm SO_3 for the formation of $K_2S_2O_7$ and 2000 ppm SO_3 for the formation of $Na_2S_2O_7$. The SO_2 level leaving the combustion zone is 2000 to 3000 ppm for most coals and fuel oil and the SO_3 level is about 30 to 40 ppm. Under these conditions the formation of pyrosulfates should not occur. In the past pyrosulfate attack has been experienced where tube surface has been exposed to direct flame impingement.[1,2]*

The alkali iron trisulfates $Na_3Fe(SO_4)_3$ have been mainly responsible for the severe loss of metal on superheaters and reheaters where the metal temperature is in the 1100 to 1300°F range. The following sequence of events is generally accepted as representing the actions occurring during the corrosion process:[1,2]

---

*Numbers designate references listed at the end of this report.

- Sodium and potassium are volatilized, in part, from the mineral matter in the high-temperature flame, forming Na_2O and K_2O.
- During combustion, pyrites are dissociated thermally and, with the organic sulfur in the coal, react with oxygen, forming mostly SO_2 and some SO_3.
- The Na_2O and K_2O then react with SO_3, either in the gas stream or on the tube, to form sodium or potassium sulfate, a low-melting material that attracts other ash particles, eventually building up a moderately thick deposit on the tube.
- SO_2 present in the flue gas is catalytically oxidized to SO_3 on iron-oxide surfaces present as tube scale. SO_3 reaches near equilibrium concentrations in localized areas near the tube (≈1000 ppm).
- The alkali sulfates, iron oxides, and SO_3 then react to form the complex sulfates $2(Na_3 \text{ or } K_3)Fe(SO_4)_3$, which are molten at about 1100°F in a high-SO_3 atmosphere (≈1000 ppm).

The cause of corrosion in refuse plants is not clear. Some investigators have attributed the metal wastage to chloride while others feel the heavy metals zinc and chloride are the responsible reactants.

The mechanism for the chloride attack is believed to begin with the deposition of alkali metal oxides, which are then converted to chlorides by the action of NaCl. Some chlorides such as NaCl may be volatilized in the flame and deposited. Some investigators believe corrosion is initiated by the conversion of chlorides to sulfates by the action of SO_2, oxygen, and moisture, thereby releasing HCl at the metal surface. The HCl formed can then react with the iron surface to form ferrous chloride, or it may be oxidized to elemental chlorine. The chlorine that is formed solely near the catalytic surface would then combine directly with the iron.[3]

When sulfur is added to the refuse, the chlorine content of the deposits decreases significantly. The effect is particularly noticeable in the 700 to 750°F zone, where chlorine concentration in the deposits is the heaviest. The addition of sulfur to bulk refuse has been reported to reduce the corrosion rates of carbon steel and stainless steels significantly. In the cofiring of refuse-coal mixtures, the initial corrosion rates of carbon steel were about an order of magnitude lower than those for 100-percent refuse, while those for stainless steels were 10 to 50 times lower.[3]

The role of chlorine in the corrosive attack is still uncertain. Cutler, et al.,[4] indicated that chlorides will not condense as an independent phase in the deposit, and the HCl will have little effect on any metal surface it contacts. Furthermore, the absorption of gaseous chloride by the deposits will not enhance their long-term corrosiveness. They do recognize, however, the fact that chlorides may deposit on tube surfaces as a result of short residence time or poor combustion.

The presence of chlorides as an independent phase on a surface, by whatever mechanism it is introduced, may be taken as an indication of enhanced rates of attack on the metal. If the general atmosphere permeating the deposit is oxidizing, then the chloride can play an active role in the corrosive process. If it is reducing, the atmosphere may cause enhanced rates of corrosion by destroying any protective oxide layer, sulfidation of the metal, etc. The chloride itself may play little or no direct part. On the other hand, Brown, DeLong, and Auld[5] show that elemental chlorine attacks carbon steel rapidly above 399°F, while the HCl attack increases rapidly above 896°F.

X-ray diffraction patterns as well as scans made with the Scanning Electron Microscope (SEM) have indicated the presence of potassium and chlorine in fly ash and deposits taken from small domestic boilers and one European boiler in which metal wastage was severe. Ferric chloride and sodium chloride, as well as $FeCl_2$ and $ZnCl_2$, produce melts at 302 to 482°F, which could be responsible for or contribute to corrosion of evaporator tubes.

Others believe the corrosion of high-temperature surfaces may be caused by a low-melting eutectic (formed by $ZnSO_4$, $NaSO_4$, and K_2SO_4) which acts as a fluxing agent permeating and destroying the protective oxide layer and resulting in severe corrosive attack.[6]

Table 2 shows that the coal ash contains 33.2 percent iron reported as Fe_2O_3. In the presence of the other major constituents (i.e., Al_2O_3 and SiO_2), the Fe_2O_3 acts as a fluxing agent, reducing the melting or softening temperature of the ash from 2800 to 2550°F under oxidizing conditions. Under reducing conditions the Fe_2O_3 is reduced to FeO, which accounts for a further reduction in melting temperature to 2160°F. The remaining minor constituents which do not volatilize (i.e., MgO and CaO) contribute little to the fluxing action. The concentration of the volatile constituents in the coal (i.e. K_2O and Na_2O) are negligible.

The Teledyne pellets contain only small amounts of iron, which exist as Fe_2O_3 rather than FeS_2 as found in coal. On the basis of the previous discussion which was directed at Eastern coals with highly acidic ashes and rich in iron as pyrites, blending of the Teledyne pellets whose ash is low in iron with coal should result in an increase in the composite ash softening temperature. This is the case for the reducing conditions but not the oxidizing conditions. The discrepancy is most likely the result of a change in iron to calcium ratio. Calcium is a basic impurity. In sufficient quantities it too can act as a fluxing agent. However, the Teledyne pellets are not as sensitive to oxidizing and reducing conditions as is the coal.

It is somewhat surprising that the laboratory analysis revealed a softening temperature for the Teledyne dRDF ash under reducing and oxidizing conditions equal to or lower than the softening temperatures reported for either one of the other two fuels under the same conditions. It is possible that the lower melting temperature is the result of a very high percentage of alkali. In instances where the Na_2O concentrations have exceeded 6 percent, a noticeable reduction in softening temperatures has been observed.

The Teledyne fuel contains an alarmingly large quantity of sodium. Its behavior after combustion in the presence of large quantities of sulfur will determine whether or not corrosion will exist. It is most important to avoid reducing conditions on the furnace walls and avoid deposition of pyritic material to inhibit the formation of the alkali pyrosulfates. It is also important to maintain metal surfaces in the convective zone below 1050°F to avoid the corrosive action of the alkali trisulfates. There do not appear to be sufficient quantities of zinc or lead to lower the threshold temperature of the trisulfate attack, nor does there appear to be sufficient chloride to be a cause for alarm.

The percentage of major constituents present can also be estimated from a knowledge of the percentage of ash, percentage of sulfur, ash fusion data, and general relationships that exist between the ash softening temperature and the ash chemistry for various rank coals, as illustrated in Figure 1. Generally, about 73 percent of the sulfur exists in the coal as pyrites (FeS_2). The remaining sulfur is present as an organically bound sulfur. Most of the iron present--about 80 percent--is bound to sulfur in the pyrites. Thus about 6.64 percent of the iron in the ash in Coal A appears as Fe_2O_3 or $FeCO_3$. If the ash is 15.5 percent of the coal, it should contain about 29-percent iron as Fe_2O_3. Since the fuel is highly volatile and contains about 4-percent sulfur, we may assume that the coal is bituminous, or the ash at least behaves as a bituminous ash. Thus according to Figure 1, the softening temperature should be about 2300°F ±100°F. No allowance is made for the presence of calcium, magnesium, or other alkalies. The ash fusion data indicate the softening temperature is about 2160°F under reducing conditions, which is only slightly below the temperature estimated from the ash chemistry. The difference between the estimated and actual softening temperature is caused by the addition of 4 percent Fe_2O_3 from the carbonates in the coal and the CaO in the limestone. Actually, there is good agreement between the measured and estimated ash softening temperature. The large difference between ash softening temperatures under reducing and oxidizing conditions is characteristic of a pyrite-rich ash.

The fireside behavior of the coal ash depends to a large extent on the quantity of pyrites present, the size distribution of ash, and the juxtaposition of the pyrites in the coal with regard to other mineral matter. If the pyrite is

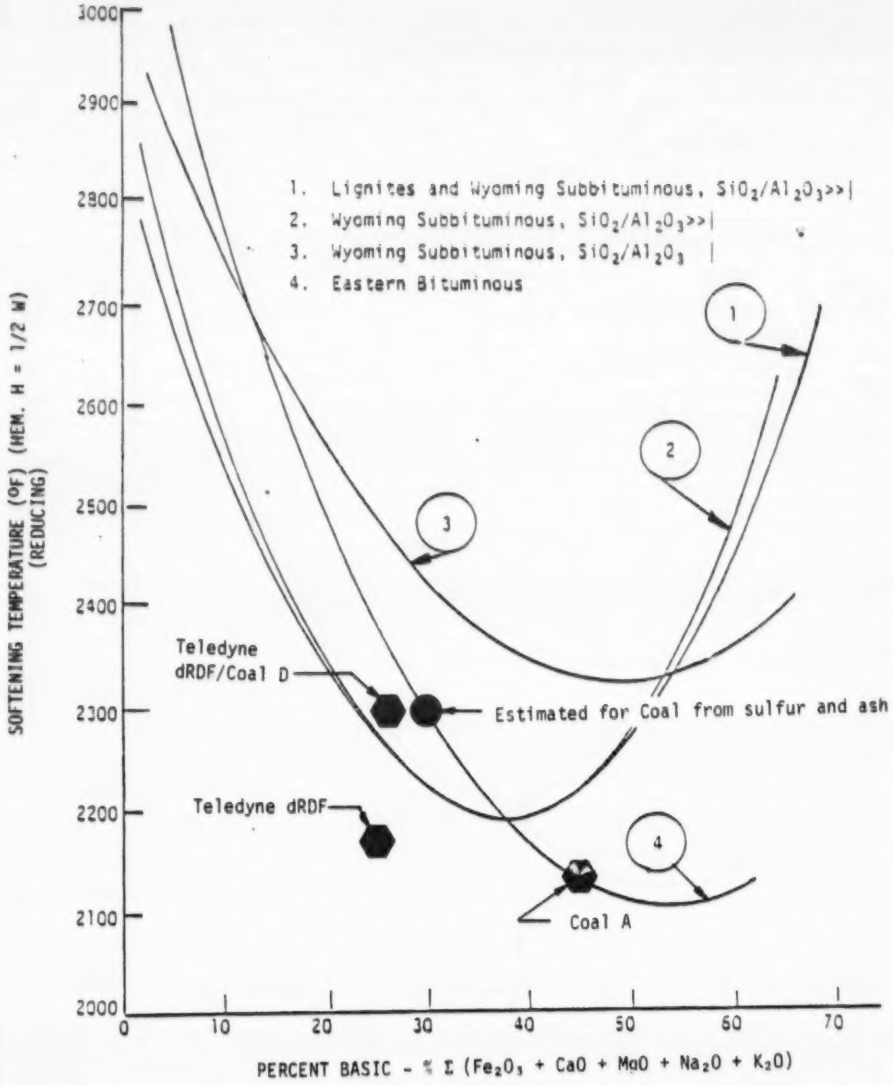


Figure 1 Influence of Percentage of Basic Constituents in the Ash on Ash Softening Temperatures for Different Rank Coals (Under reducing conditions)

found as finely divided material intimately mixed with other mineral material, the ash will have a melting temperature similar to that projected by the ASTM ash fusion cones. Little segregation of mineral matter will occur during combustion, and oxidation of the pyrites should be complete before contact with the heat exchanger surface. On the other hand, if pyrites exist as a coarse, independent specie, oxidation may be delayed, permitting the formation of a semimolten particle consisting of FeS + S, which may contact and stick to heat-transfer surfaces. Mixtures of FeS + S are known to form melts at temperatures as low as 1000°F. Under reducing conditions the completely oxidized form of pyrites (i.e., FeO) may form a melt at a temperature as low as 1950°F. Large particles of pyrites can be responsible for clinkers. Smaller particles blown free of the bed may stick to the walls if not completely oxidized. They can also be responsible for corrosion caused by pyrosulfates or alkali trisulfates under appropriate environmental conditions. Since this is a high-sulfur coal, a potential corrosion situation exists. In the event corrosion is experienced in the field, care must be taken in identifying the attack to be certain the refuse is not mistakenly identified as the source of the problem.

Ash deposit samples were taken from the following locations:

Coal A	Teledyne dRDF/Coal D Blend
Screen	Screen
Upper North Sidewall	Front Wall
Lower North Sidewall	Lower North Sidewall
	Lower South Sidewall

The samples were analyzed for ash chemistry (Tables 3 and 4), melting temperatures using thermal analysis (DTA--differential thermal analysis and TGA--thermogravimetric analysis), and surface morphology using the SEM.

The thermograms (Figures 2 through 15) indicate that there is no reaction taking place or melt formed in the deposits below 2195°F, except for the ash removed from the screen tubes. An exotherm appears in screen tube deposits at about 812 to 1120°F under air when firing coal (Figure 6) and--to a lesser extent--when firing the coal/dRDF (Figure 13). The exotherm is characteristic of pyrites. However, the TGA does not show evidence of a loss in weight corresponding to the loss in sulfur. Also one would not expect the reaction to take place when firing the dRDF unless the tubes were not clean or the furnace was not purged of pyrites. The chemical analysis indicates an iron enrichment in both cases, with minor concentrations of sulfur reported as SO_3. Despite the fact that the TGA shows no signs of a weight loss coincident with an exotherm, we believe the exotherm is the result of a slight contamination of the deposit by pyrites.

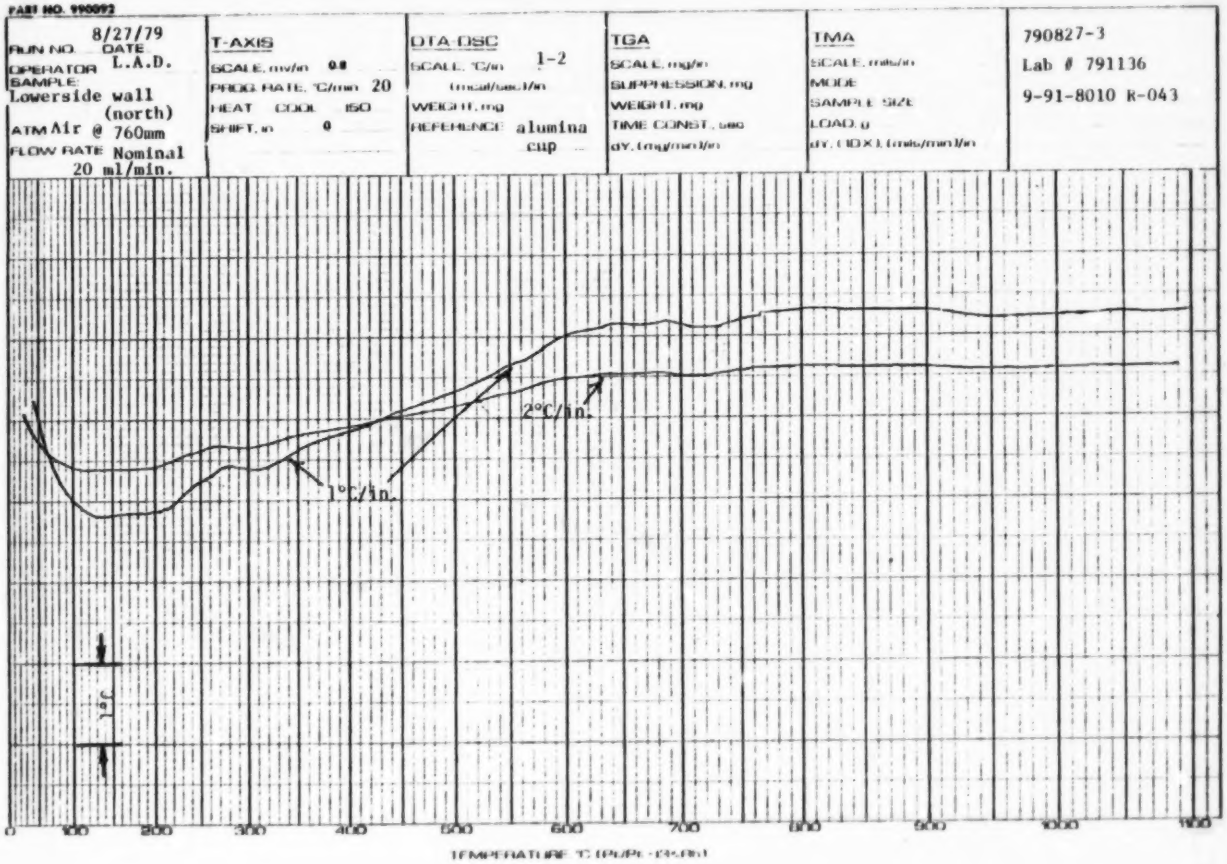
The chemical analysis indicates the slag is enriched with iron typical of furnace deposits attributed to free pyrites in the coal. This was true for all the coal baseline deposits and the screen tube deposit from the dRDF/Coal D test burn. Deposits formed while firing dRDF/Coal D Blend are considerably enriched with SiO_2, Al_2O_3, and CaO. There is also a slight enrichment of the minor constituents, Na_2O and K_2O. Lead and zinc appear to be missing. There is nothing in the chemical analyses of the deposits that cause concern about a corrosion problem.

Table 3 Ash Chemistry (Coal A baseline)

Elemental Oxide	% by Weight		
	Screen Tubes	Upper North Sidewall	Lower North Sidewall
SiO_2	16.2	11.0	30.8
Al_2O_3	8.4	6.5	15.4
TiO_2	0.1	0.5	0.5
Fe_2O_3	63.9	76.9	47.0
CaO	1.6	1.0	3.1
MgO	0.3	0.2	1.1
Na_2O	0.2	0.2	0.2
K_2O	<0.1	<0.1	<0.1
ZnO	<0.1	<0.1	<0.1
P_2O_5	0.1	<0.1	0.2
MnO_2	<0.1	<0.1	<0.1
NiO	0.3	0.4	0.4
Cl	0.2	0.2	0.1
SO_3	7.8	1.0	0.1
PbO	0.06	0.08	0.1

Table 4 Ash Analysis (Teledyne dRDF/Coal D Blend burn)

Elemental Oxide	% by Weight			
	Screen Tubes	Front Wall	Lower North Sidewall	Lower South Sidewall
SiO_2	26.5	47.2	46.2	43.7
Al_2O_3	9.4	16.4	19.0	18.4
TiO_2	1.1	1.9	1.8	1.8
Fe_2O_3	46.9	19.5	19.0	19.4
CaO	4.5	6.1	6.2	6.7
MgO	1.1	1.6	1.6	1.6
Na_2O	1.5	3.3	2.8	3.0
K_2O	0.8	<0.1	1.2	1.2
ZnO	0.4	0.5	0.1	0.2
P_2O_5	0.4	0.5	0.5	0.4
MnO_2	<0.1	<0.1	<0.1	<0.1
NiO	0.3	0.3	0.3	0.4
Cl	0.3	0.2	0.3	0.2
SO_3	5.3	0.8	0.6	1.2
PbO	0.31	0.1	0.08	0.11



PART NO. 990092

RUN NO. DATE 8/27/79
OPERATOR L.A.D.
SAMPLE Lowerside wall (north)
ATM Air @ 760mm
FLOW RATE Nominal 20 ml/min.

T-AXIS
SCALE, mv/in 0.8
PROG. RATE, °C/min 20
HEAT COOL 150
SHIFT, in 0

DTA-DSC
SCALE, °C/in 1-2
(mcal/sec)/in
WEIGHT, mg
REFERENCE alumina cup

TGA
SCALE, mg/in
SUPPRESSION, mg
WEIGHT, mg
TIME CONST., sec
dY, (mg/min)/in

TMA
SCALE, mils/in
MODE
SAMPLE SIZE
LOAD, g
dY, (10X), (mils/min)/in

790827-3
Lab # 791136
9-91-8010 R-043

1°C/in.
2°C/in.
ΔT
0
100
200
300
400
500
600
700
800
900
1000
1100
TEMPERATURE °C (Pt/Pt-13%Rh)

Figure 2 Differential Thermal Analysis Thermogram of Slag Accumulated on Lower North Sidewall of Furnace While Firing Coal A (Under oxidizing conditions)

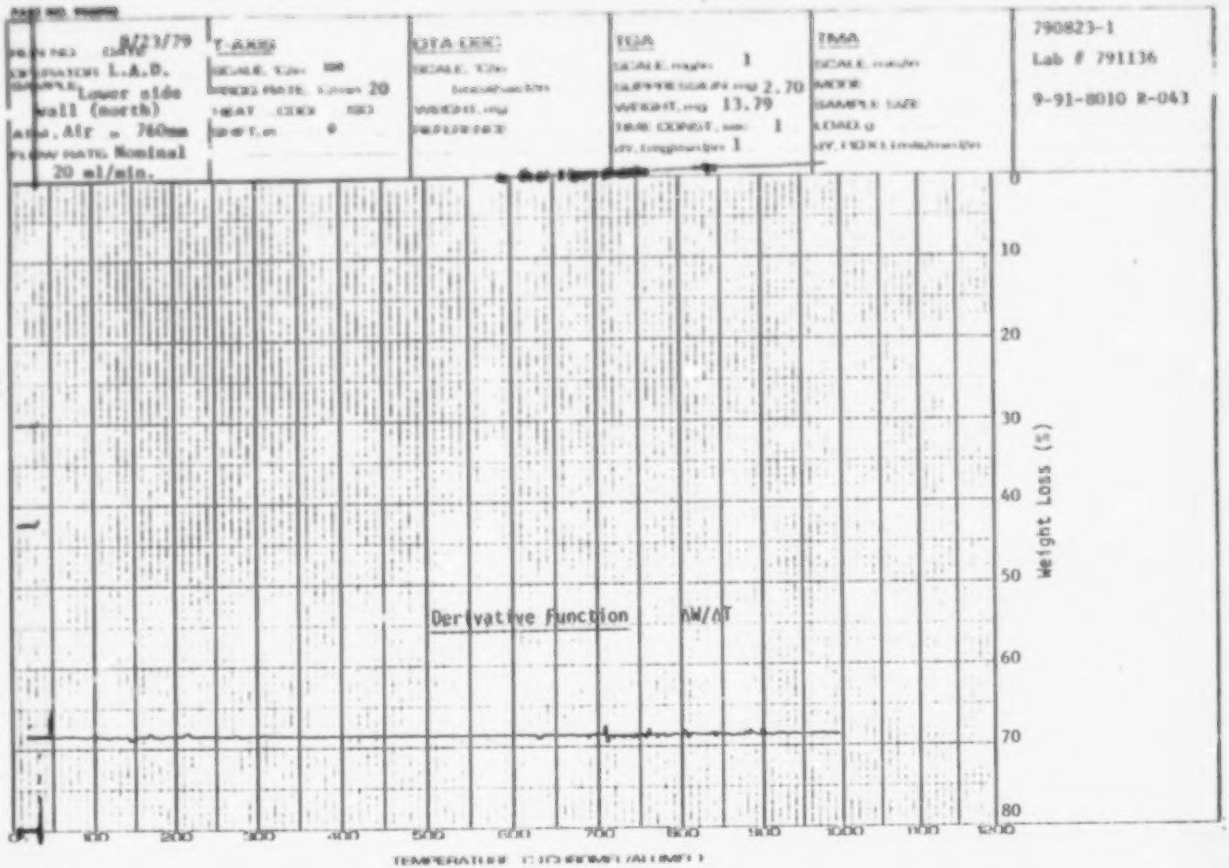
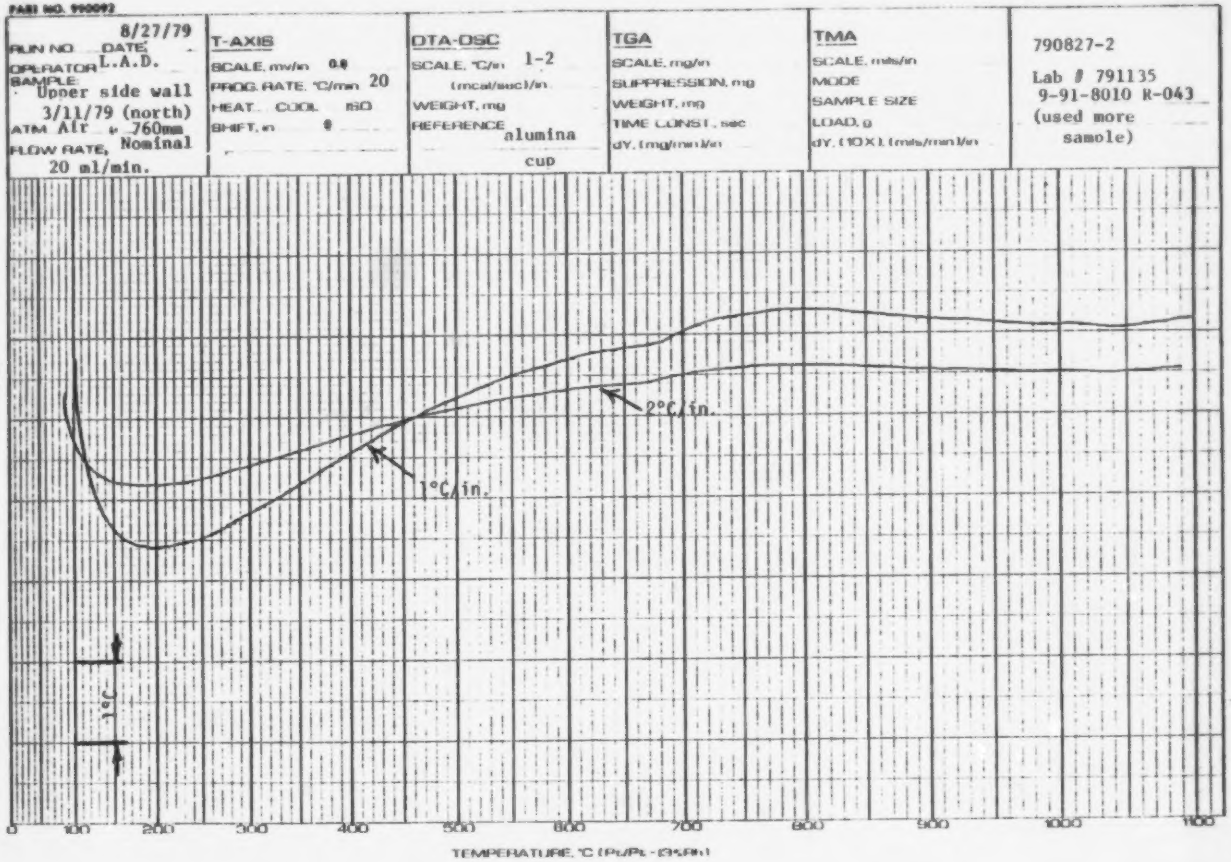


Figure 3 Thermogravimetric Analysis Thermogram of Slag Accumulated on Lower North Sidewall of Furnace While Firing Coal A (Under oxidizing conditions)



PARI NO. 990092

RUN NO. DATE 8/27/79
OPERATOR L.A.D.
SAMPLE: Upper side wall 3/11/79 (north)
ATM Air ÷ 760mm
FLOW RATE, Nominal 20 ml/min.

T-AXIS
SCALE, mv/in 0.0
PROG. RATE, °C/min 20
HEAT. COOL ISO
SHIFT, in 0

DTA-DSC
SCALE, °C/in 1-2
(mcal/sec)/in
WEIGHT, mg
REFERENCE alumina cup

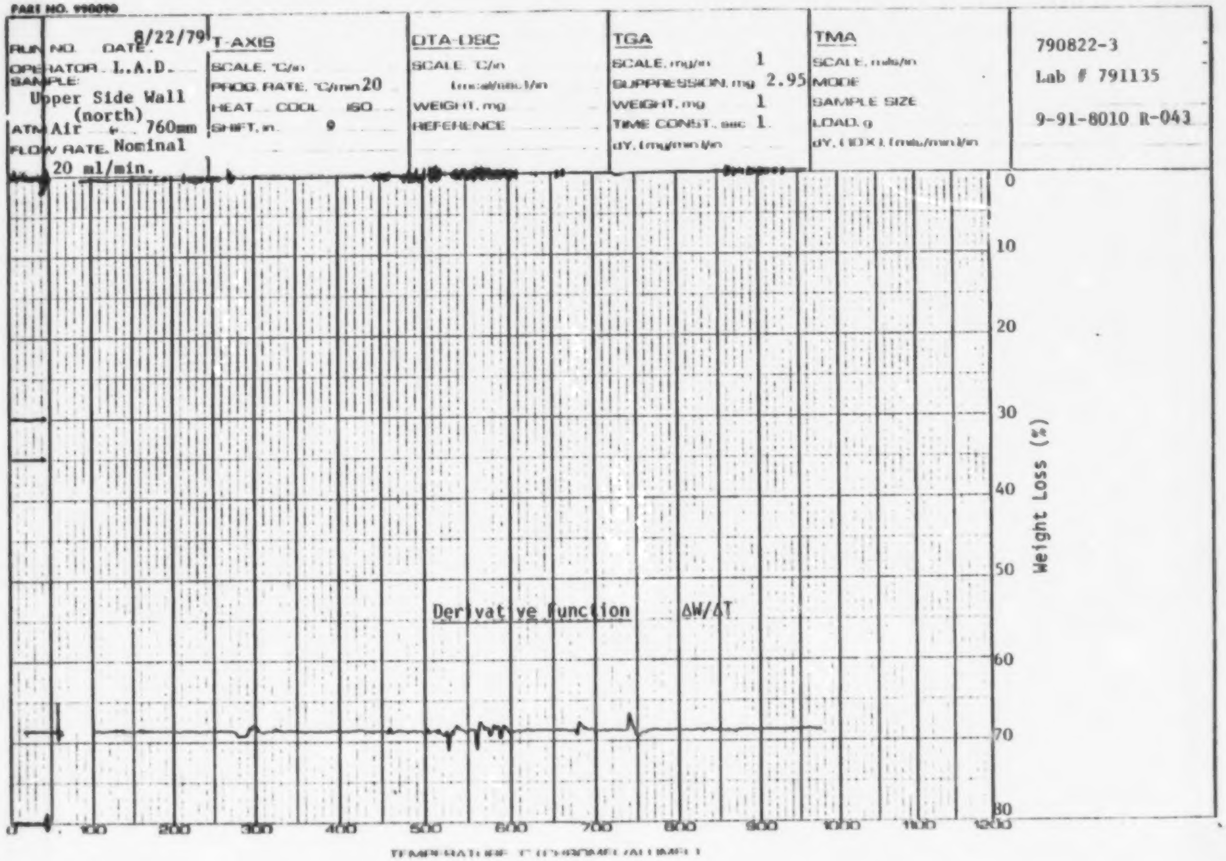
TGA
SCALE, mg/in
SUPPRESSION, mg
WEIGHT, mg
TIME CONST., sec
dY, (mg/min)/in

TMA
SCALE, mils/in
MODE
SAMPLE SIZE
LOAD, g
dY, (10X), (mils/min)/in

790827-2
Lab # 791135
9-91-8010 R-043
(used more sample)

2°C/in.
1°C/in.
1°C
0
100
200
300
400
500
600
700
800
900
1000
1100
TEMPERATURE, °C (Pt/Pt - 13%Rh)

Figure 4 Differential Thermal Analysis Thermogram of Slag Accumulated on Upper North Sidewall of Furnace While Firing Coal A (Under oxidizing conditions)



PART NO. 990090

RUN NO. DATE 8/22/79
OPERATOR L.A.D.
SAMPLE: Upper Side Wall (north)
ATM Air ← 760mm
FLOW RATE. Nominal 20 ml/min.

T-AXIS
SCALE, °C/in
PROG. RATE, °C/min 20
HEAT COOL ISO
SHIFT, in. 9

DTA-DSC
SCALE °C/in
(mcal/sec.)/in
WEIGHT, mg
REFERENCE

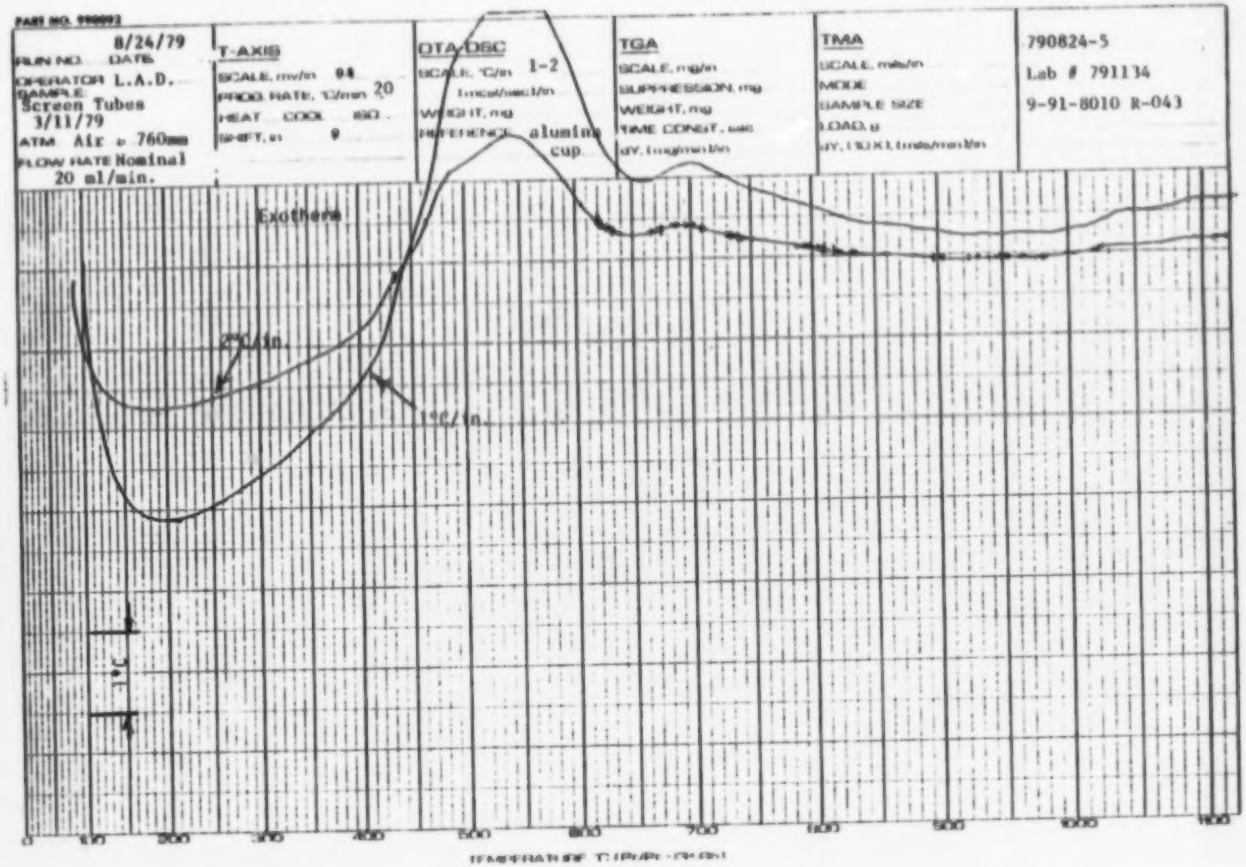
TGA
SCALE, mg/in 1
SUPPRESSION, mg 2.95
WEIGHT, mg 1
TIME CONST., sec 1.
dY, (mg/min)/in

TMA
SCALE, mils/in
MODE
SAMPLE SIZE
LOAD, g
dY, (10X), (mils/min)/in

790822-3
Lab # 791135
9-91-8010 R-043

Derivative function ΔW/ΔT
Weight Loss (%)
0
10
20
30
40
50
60
70
80
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
TEMPERATURE °C (CHROMEL/ALUMEL)

Figure 5 Thermogravimetric Analysis Thermogram of Slag Accumulated on Upper North Sidewall of Furnace While Firing Coal A (Under oxidizing conditions)



PART NO. 990092

RUN NO. DATE 8/24/79

OPERATOR L.A.D.

SAMPLE Screen Tubes 3/11/79

ATM Air @ 760mm

FLOW RATE Nominal 20 ml/min.

T-AXIS

SCALE, mv/in 04

PROG RATE, °C/min 20

HEAT COOL ISO.

SHIFT, in 9

DTA/DSC

SCALE, °C/in 1-2

(mcal/sec)/in

WEIGHT, mg

REFERENCE alumina cup

TGA

SCALE, mg/in

SUPPRESSION, mg

WEIGHT, mg

TIME CONST., sec

dY, (mg/min)/in

TMA

SCALE, mils/in

MODE

SAMPLE SIZE

LOAD, g

dY, (10 X), (mils/min)/in

790824-5

Lab # 791134

9-91-8010 R-043

Exotherm
2°C/in.
1°C/in.
1°C
0
100
200
300
400
500
600
700
800
900
1000
1100
TEMPERATURE °C

Figure 6 Differential Thermal Analysis Thermogram of Slag Accumulated on Screen Tubes While Firing Coal A (Under oxidizing conditions)

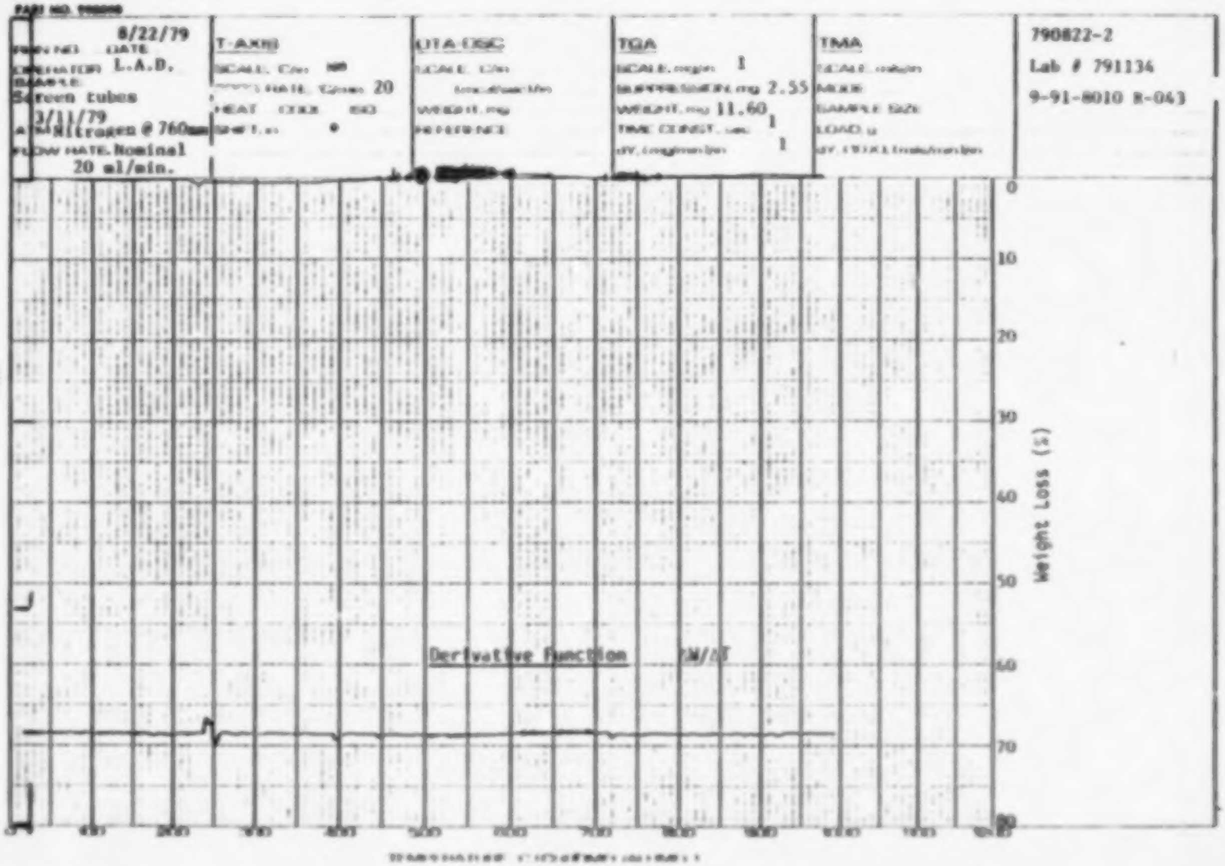


Figure 7 Thermogravimetric Analysis Thermogram of Slag Accumulated on Screen Tubes While Firing Coal A (Under oxidizing conditions)

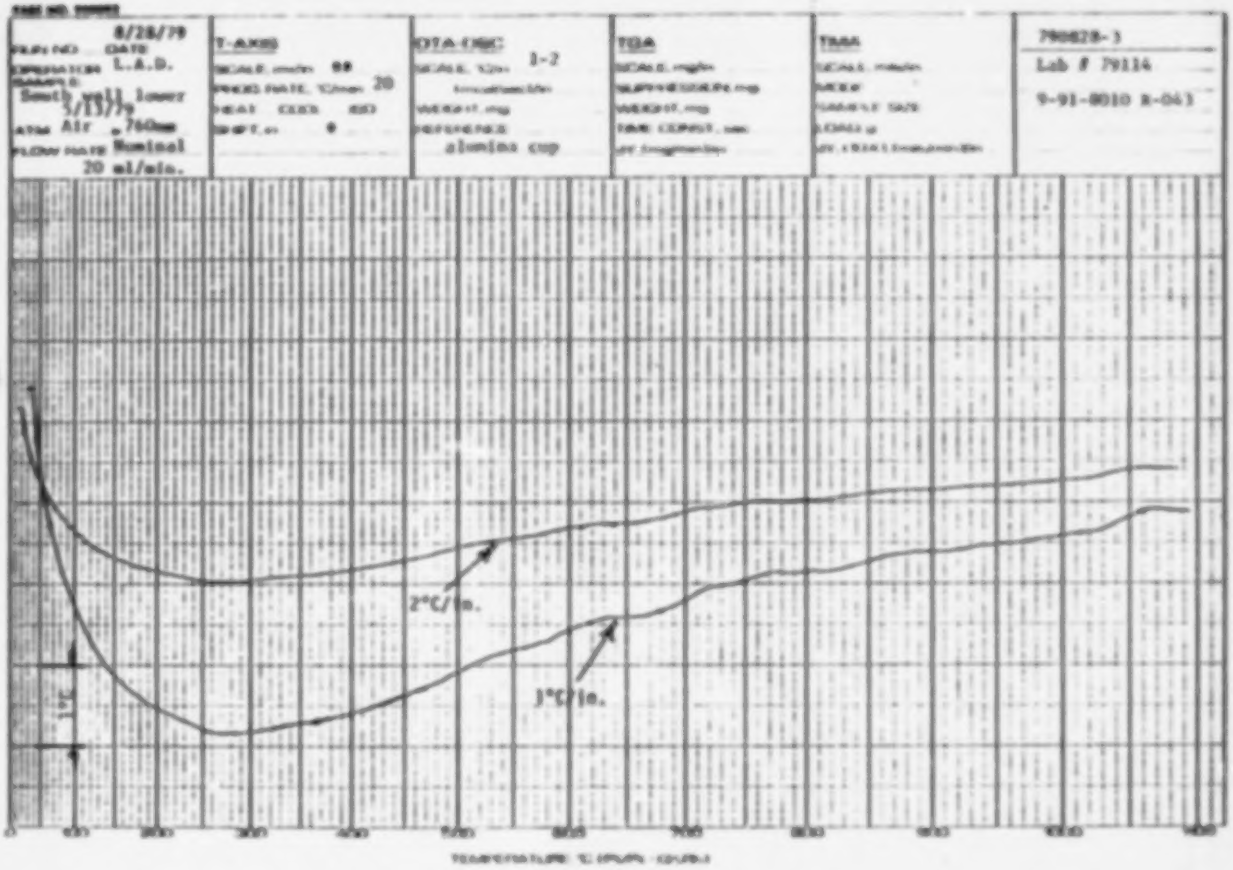


Figure 8 Differential Thermal Analysis Thermogram of Slag Accumulated on Lower South Sidewall of Furnace While Firing Teledyne dRDF/Coal D Blend (Under oxidizing conditions)

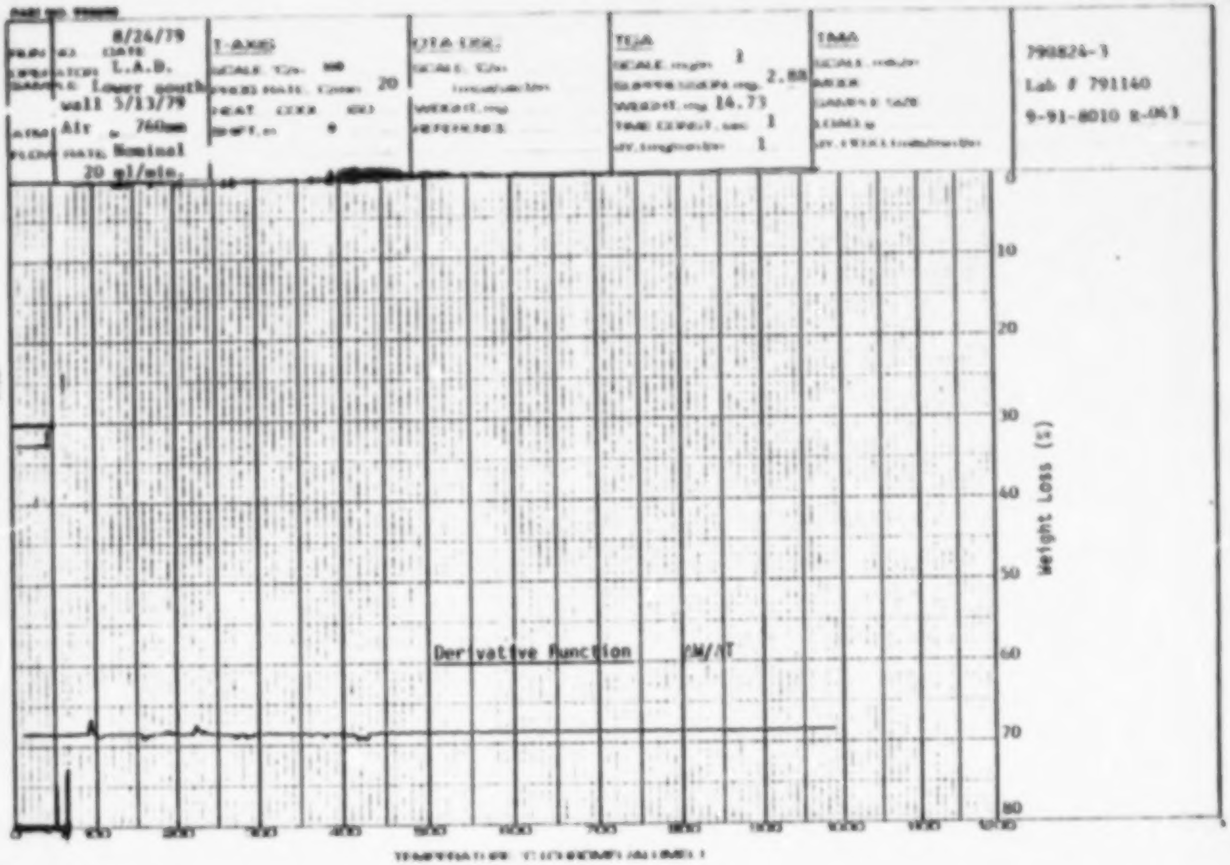
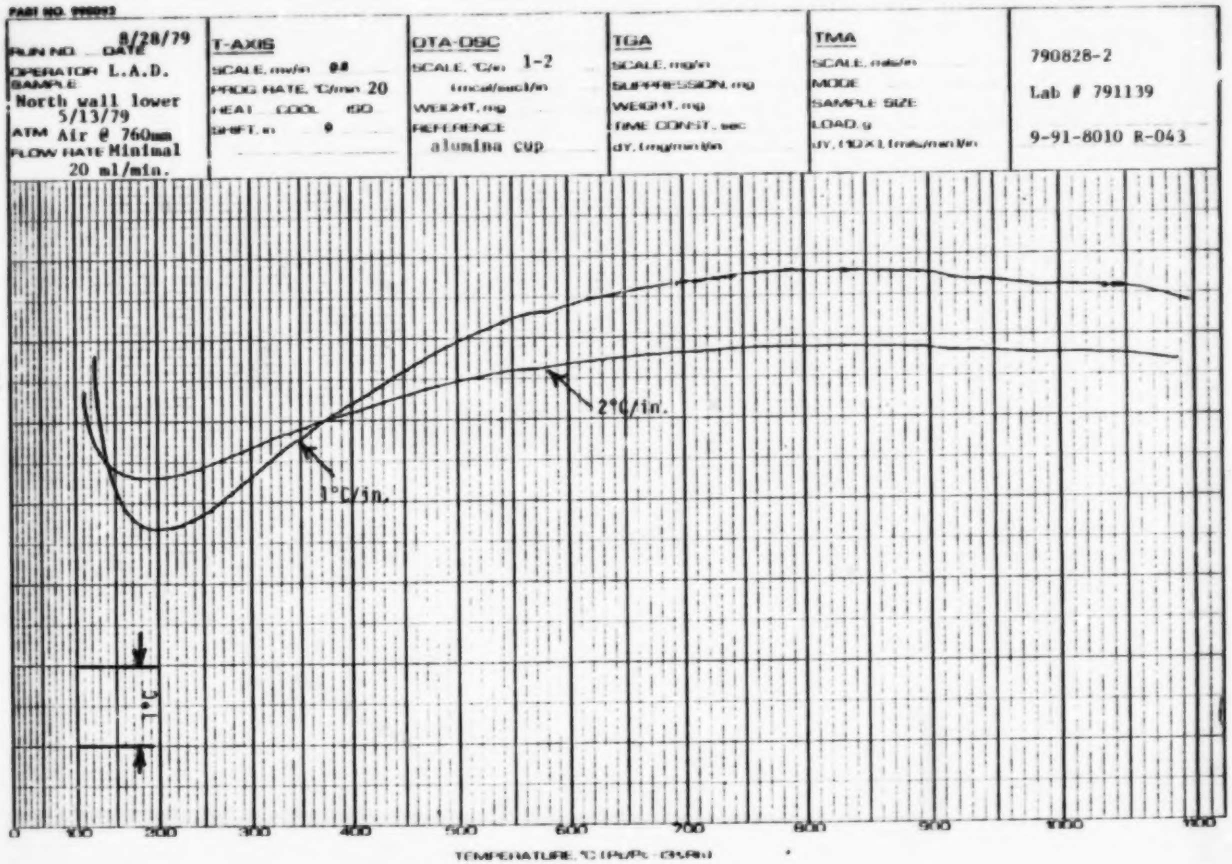


Figure 9 Thermogravimetric Analysis Thermogram of Slag Accumulated on Lower South Sidewall of Furnace While Firing Teledyne dRDF/Coal D Blend (Under oxidizing conditions)



PART NO. 990093

RUN NO. DATE 8/28/79
OPERATOR L.A.D.
SAMPLE North wall lower 5/13/79
ATM Air @ 760mm
FLOW RATE Minimal 20 ml/min.

T-AXIS
SCALE, mv/in 0.8
PROG RATE, °C/min 20
HEAT COOL ISO
SHIFT, in 0

DTA-DSC
SCALE, °C/in 1-2
(mcal/sec)/in
WEIGHT, mg
REFERENCE alumina cup

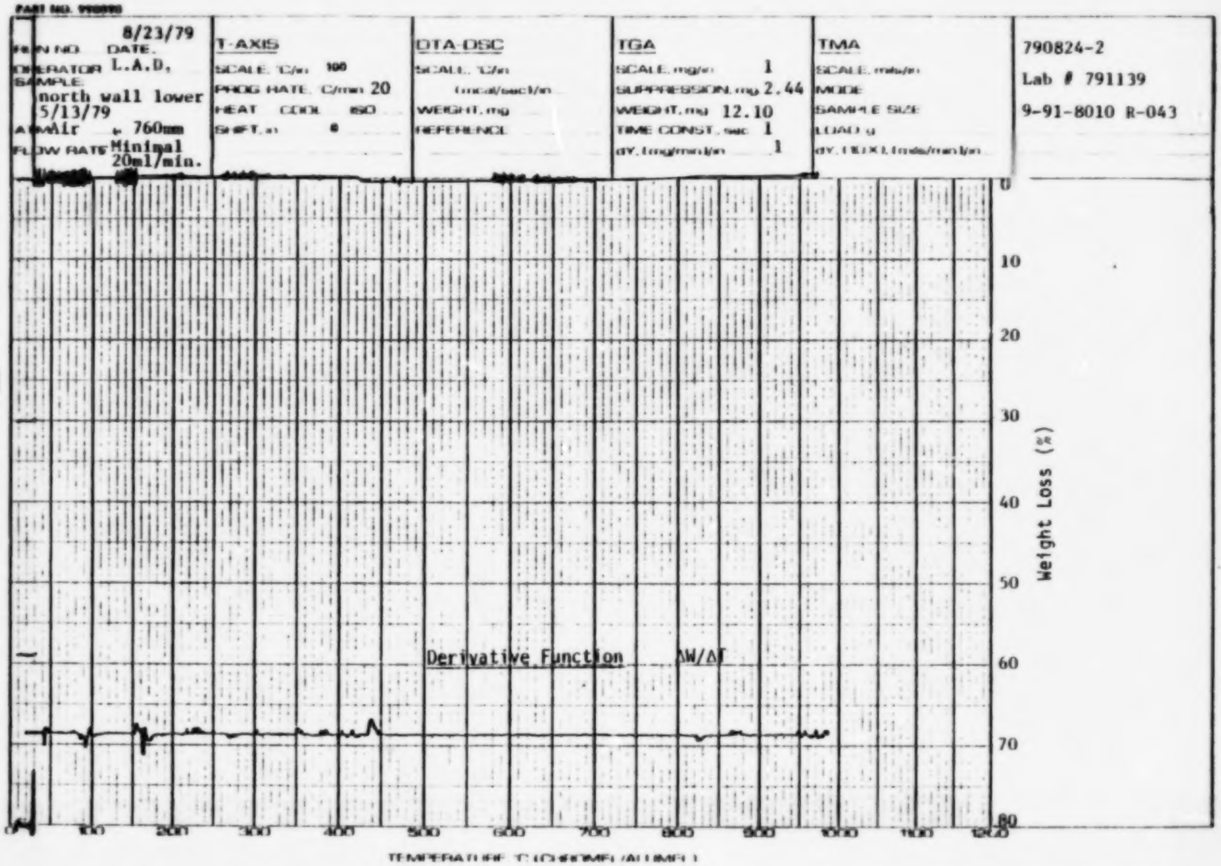
TGA
SCALE, mg/in
SUPPRESSION, mg
WEIGHT, mg
TIME CONST., sec
dY, (mg/min)/in

TMA
SCALE, mils/in
MODE
SAMPLE SIZE
LOAD, g
dY, (10 X), (mils/min)/in

790828-2
Lab # 791139
9-91-8010 R-043

2°C/in.
1°C/in.
1°C
0
100
200
300
400
500
600
700
800
900
1000
1100
TEMPERATURE, °C (Pt/Pt-13%Rh)

Figure 10 Differential Thermal Analysis Thermogram of Slag Accumulated on Lower North Sidewall of Furnace While Firing Teledyne dRDF/Coal D Blend (Under oxidizing conditions)



RUN NO. DATE 8/23/79
OPERATOR L.A.D.
SAMPLE north wall lower 5/13/79
ATM Air + 760mm
FLOW RATE Minimal 20ml/min.

T-AXIS
SCALE °C/in 100
PROG RATE °C/min 20
HEAT COOL ISO
SHIFT, in 0

DTA-DSC
SCALE °C/in (mcal/sec)/in
WEIGHT, mg
REFERENCE

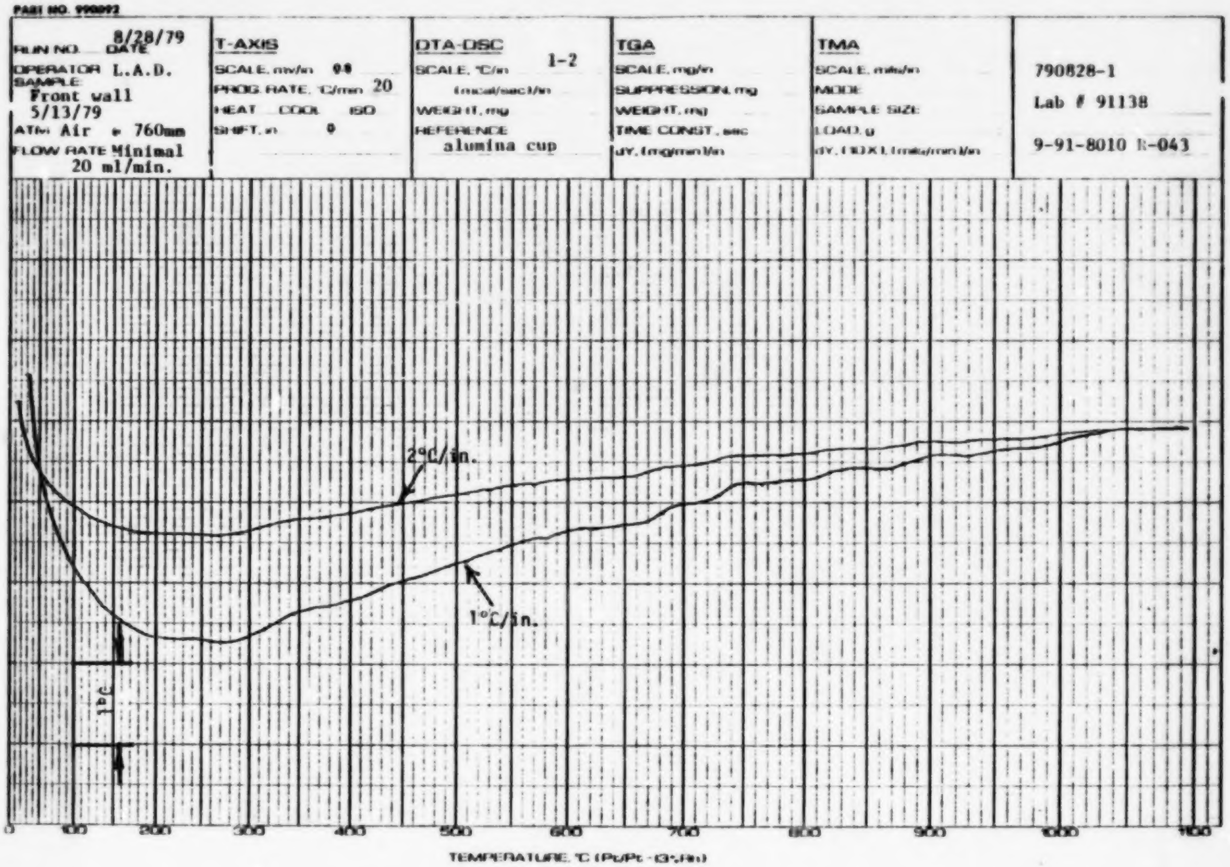
TGA
SCALE, mg/in 1
SUPPRESSION, mg 2.44
WEIGHT, mg 12.10
TIME CONST, sec 1
dY, (mg/min)/in 1

TMA
SCALE, mils/in
MODE
SAMPLE SIZE
LOAD, g
dY, (DDX), (mils/min)/in

790824-2
Lab # 791139
9-91-8010 R-043

Derivative Function ΔW/ΔT
Weight Loss (%)
0
10
20
30
40
50
60
70
80
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
TEMPERATURE °C (CHROMEL/ALUMEL)

Figure 11 Thermogravimetric Analysis Thermogram of Slag Accumulated on Lower North Sidewall of Furnace While Firing Teledyne dRDF/Coal D Blend (Under oxidizing conditions)



PART NO. 990092

RUN NO. DATE 8/28/79
OPERATOR L.A.D.
SAMPLE:
Front wall
5/13/79
ATM Air @ 760mm
FLOW RATE Minimal
20 ml/min.

T-AXIS
SCALE, mv/in 0.8
PROG. RATE, °C/min 20
HEAT COOL ISO
SHIFT, in 0

DTA-DSC
SCALE, °C/in 1-2
(mcal/sec)/in
WEIGHT, mg
REFERENCE
alumina cup

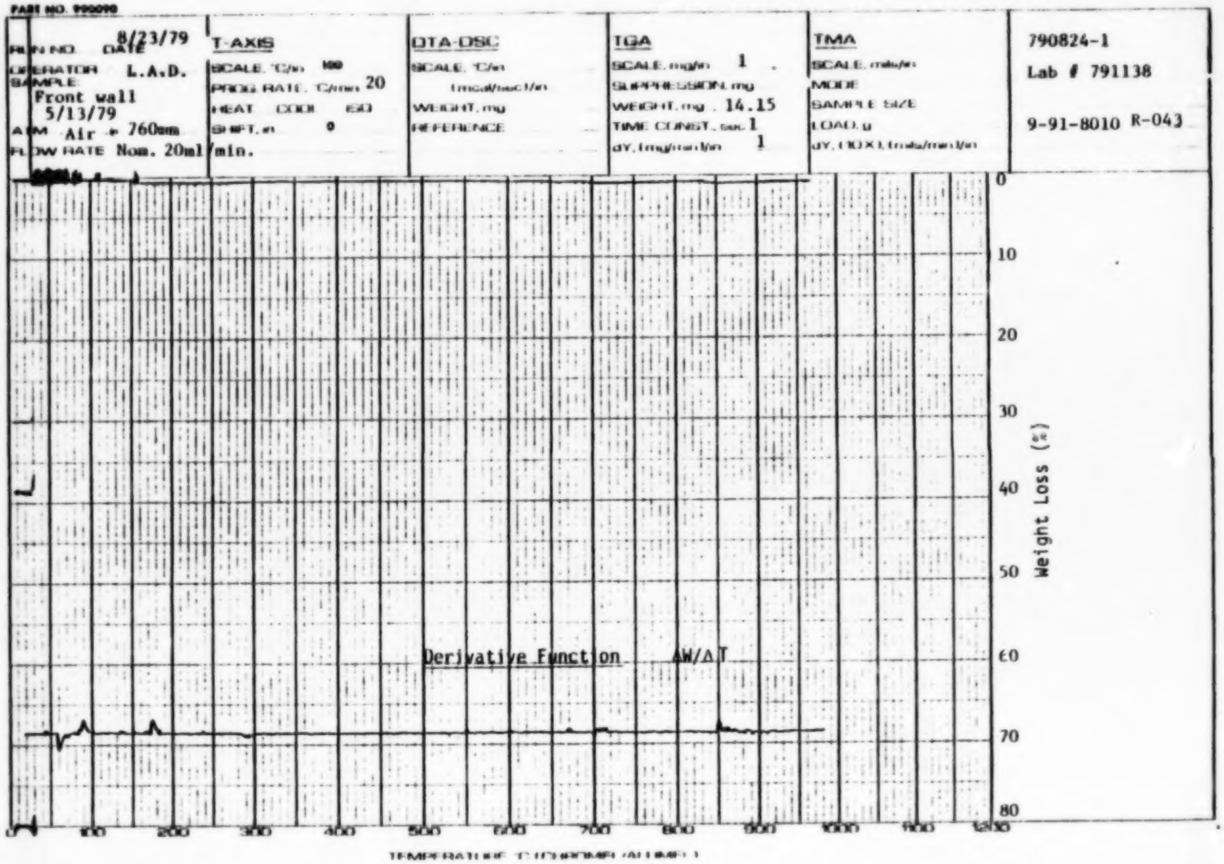
TGA
SCALE, mg/in
SUPPRESSION, mg
WEIGHT, mg
TIME CONST., sec
dY, (mg/min)/in

TMA
SCALE, mils/in
MODE
SAMPLE SIZE
LOAD, g
dY, (10 X), (mils/min)/in

790828-1
Lab # 91138
9-91-8010 R-043

2°C/in.
1°C/in.
ϑ_{al}
0
100
200
300
400
500
600
700
800
900
1000
1100
TEMPERATURE, °C (Pt/Pt-13%Rh)

Figure 12 Differential Thermal Analysis Thermogram of Slag Accumulated on Front Wall of Furnace While Firing Teledyne dRDF/Coal D Blend (Under oxidizing conditions)


PART NO. 990090

RUN NO. DATE 8/23/79
OPERATOR L.A.D.
SAMPLE: Front wall 5/13/79
ATM Air + 760mm
FLOW RATE Nom. 20ml/min.

T-AXIS
SCALE, °C/in 100
PROG RATE, °C/min 20
HEAT COOL ISO
SHIFT, in 0

DTA-DSC
SCALE, °C/in
(mcal/sec)/in
WEIGHT, mg
REFERENCE

TGA
SCALE, mg/in 1
SUPPRESSION, mg
WEIGHT, mg 14.15
TIME CONST, sec 1
dY, (mg/min)/in 1

TMA
SCALE, mils/in
MODE
SAMPLE SIZE
LOAD, g
dY, (10 X), (mils/min)/in

790824-1
Lab # 791138
9-91-8010 R-043

0
10
20
30
40
50
60
70
80
Weight Loss (%)
Derivative Function ΔW/ΔT
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
TEMPERATURE °C (CHROMEL/ALUMEL)

Figure 13 Thermogravimetric Analysis Thermogram of Slag Accumulated on the Front Wall of Furnace While Firing Teledyne dRDF/Coal D Blend (Under oxidizing conditions)

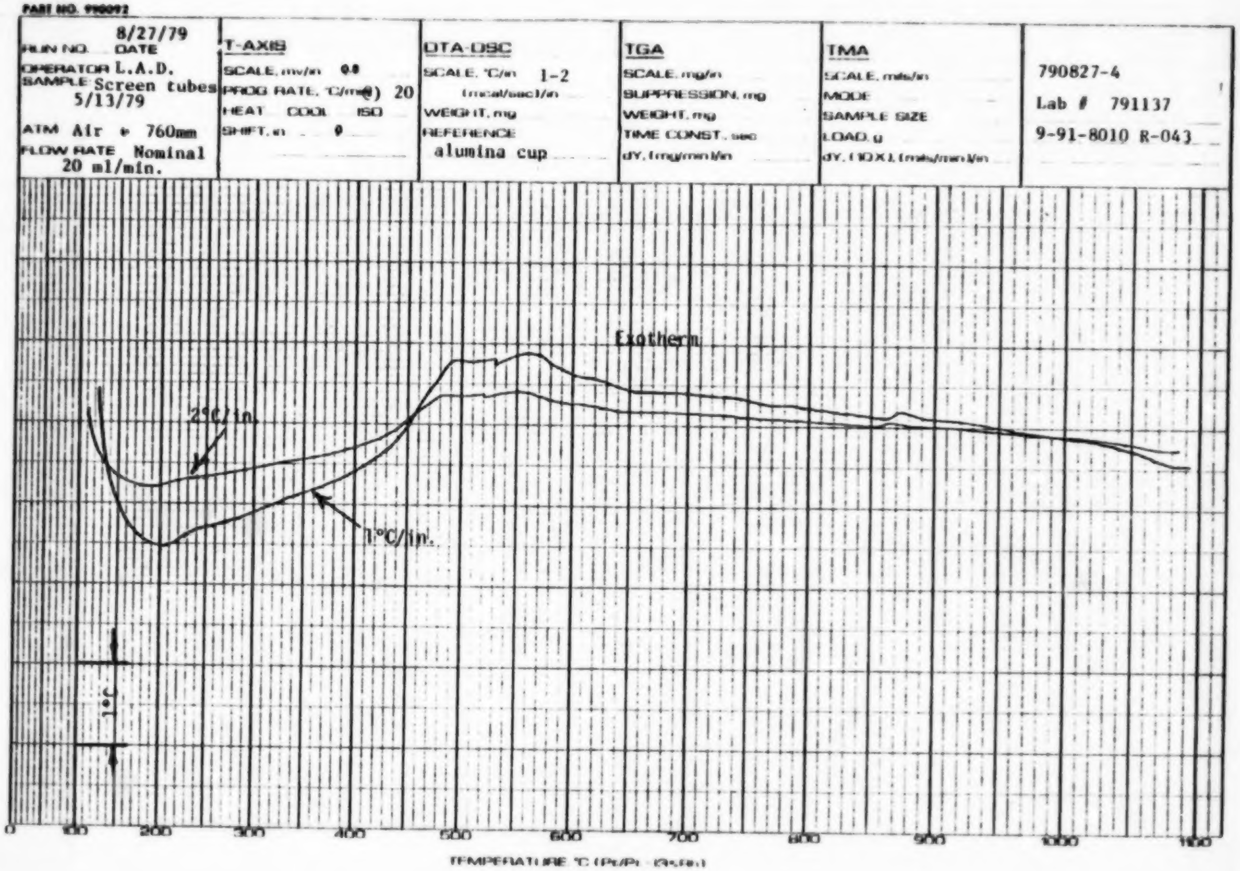
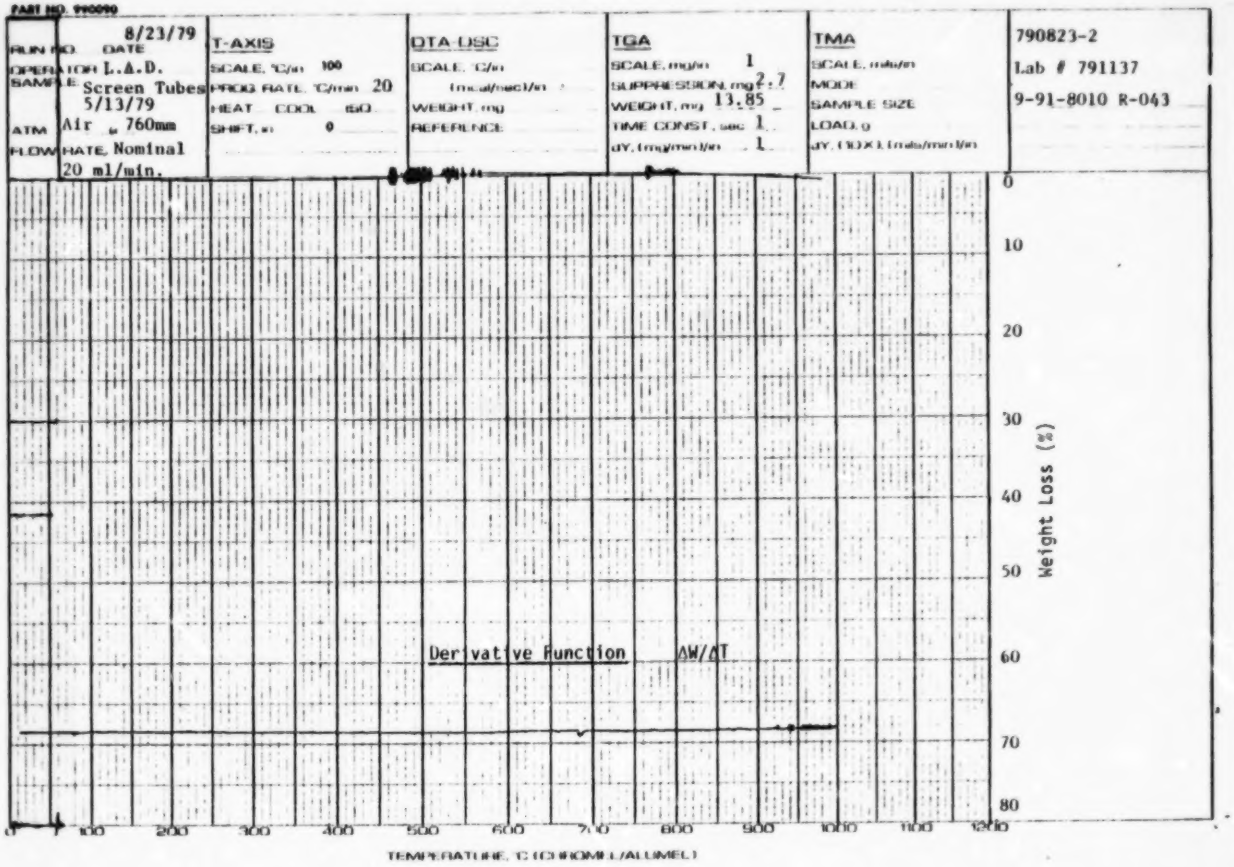


Figure 14 Differential Thermal Analysis Thermogram of Slag Accumulated on Screen Tubes While Firing Teledyne dRDF/Coal D Blend (Under oxidizing conditions)



PART NO. 990090

RUN NO. DATE 8/23/79
OPERATOR L.A.D.
SAMPLE Screen Tubes 5/13/79
ATM Air @ 760mm
FLOW RATE Nominal 20 ml/min.

T-AXIS
SCALE, °C/in 100
PROG RATE, °C/min 20
HEAT COOL ISO
SHIFT, in 0

DTA-DSC
SCALE, °C/in
(mcal/sec)/in
WEIGHT, mg
REFERENCE

TGA
SCALE, mg/in 1
SUPPRESSION, mg 2.7
WEIGHT, mg 13.85
TIME CONST, sec 1
dY, (mg/min)/in 1

TMA
SCALE, mils/in
MODE
SAMPLE SIZE
LOAD, g
dY, (10X), (mils/min)/in

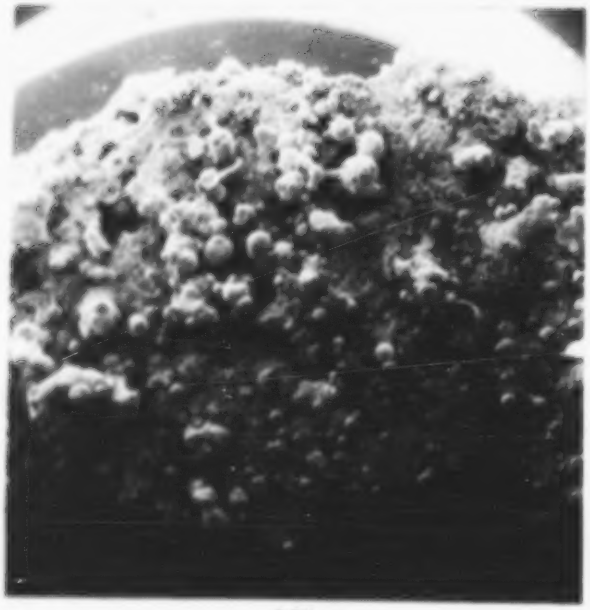
790823-2
Lab # 791137
9-91-8010 R-043

Figure 15 Thermogravimetric Analysis Thermogram of Slag Accumulated on Screen Tubes While Firing Teledyne dRDF/Coal D Blend (Under oxidizing conditions)

SEM photomicrographs and photomacrographs made of the ash deposits include deposits from Coal A (Figures 16 through 22), the Teledyne dRDF/Coal D Blend (Figures 23 through 28), and another blend test burn. This other blend (Figures 29 through 34) included damaged dRDF pellets produced by the National Center for Resource Recovery (NCRR). The net result of the damage was a change in shape and more fines. The following table identifies the photomicrographs by location and fuel.

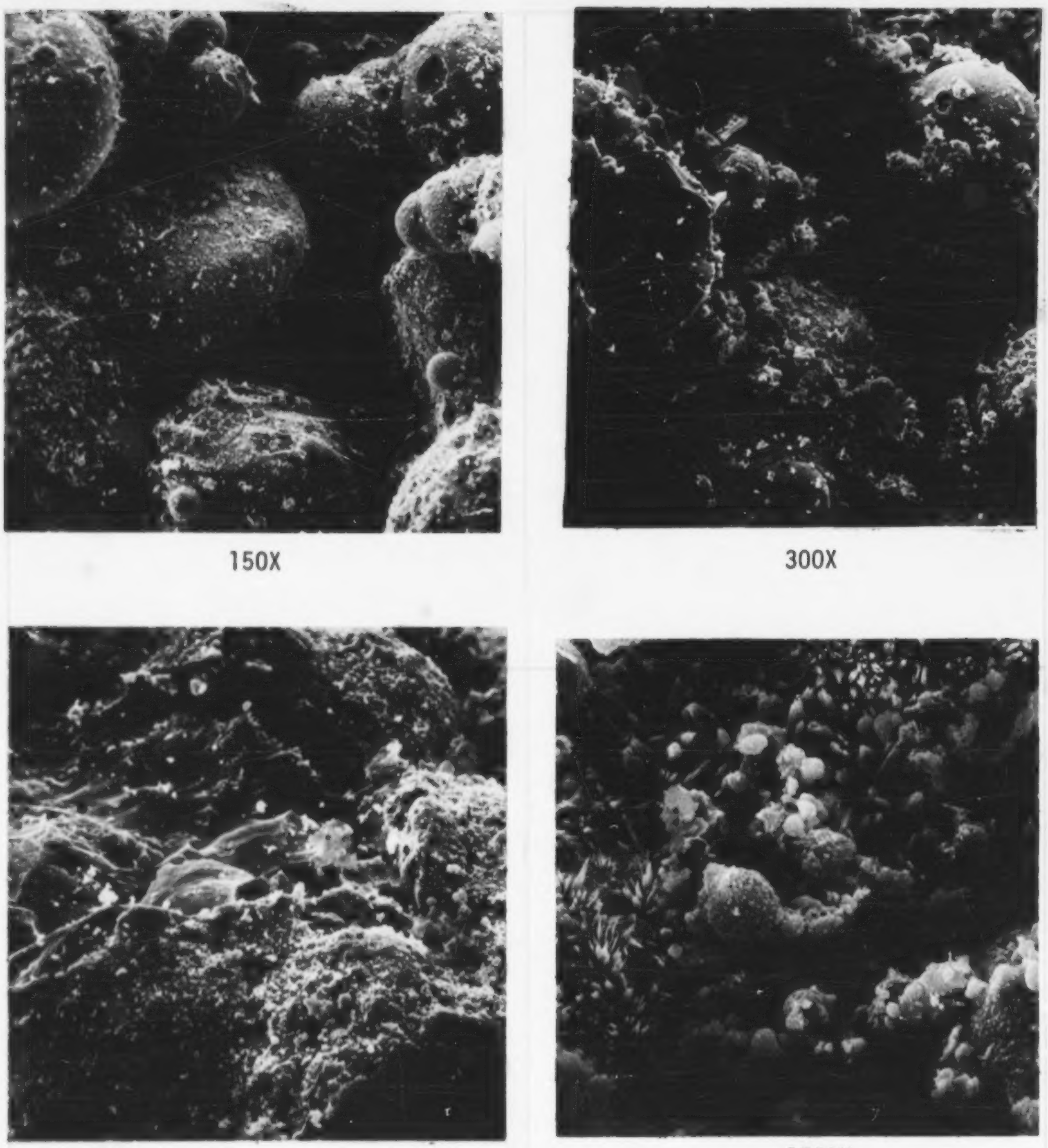
Fuel	Coal A	Teledyne dRDF/ Coal D Blend	NCRR dRDF/ Coal B Blend
Sample Location			
Screen			
Inner surface	16	---	---
Outer surface	17	23	29
Inner surface	18	24	30
Cross section	---	25	31
Front Wall	---	26	32
Upper North Sidewall			
Rough outer surface	19	---	---
Outer surface	20	---	---
Inner surface	---	---	34
Lower North Sidewall			
Outer surface	21	---	---
Inner surface	---	---	33
Cross section	22	27	---
Lower South Sidewall			
Cross section	---	28	---

The photomicrographs suggest that deposits are forming as a result of the deposition of semimolten particles in the range of 300 μm or less. From the



15X

Figure 16 SEM Photomicrograph of Slag Accumulated on Screen Tube While Firing Coal A (Inner Surface)



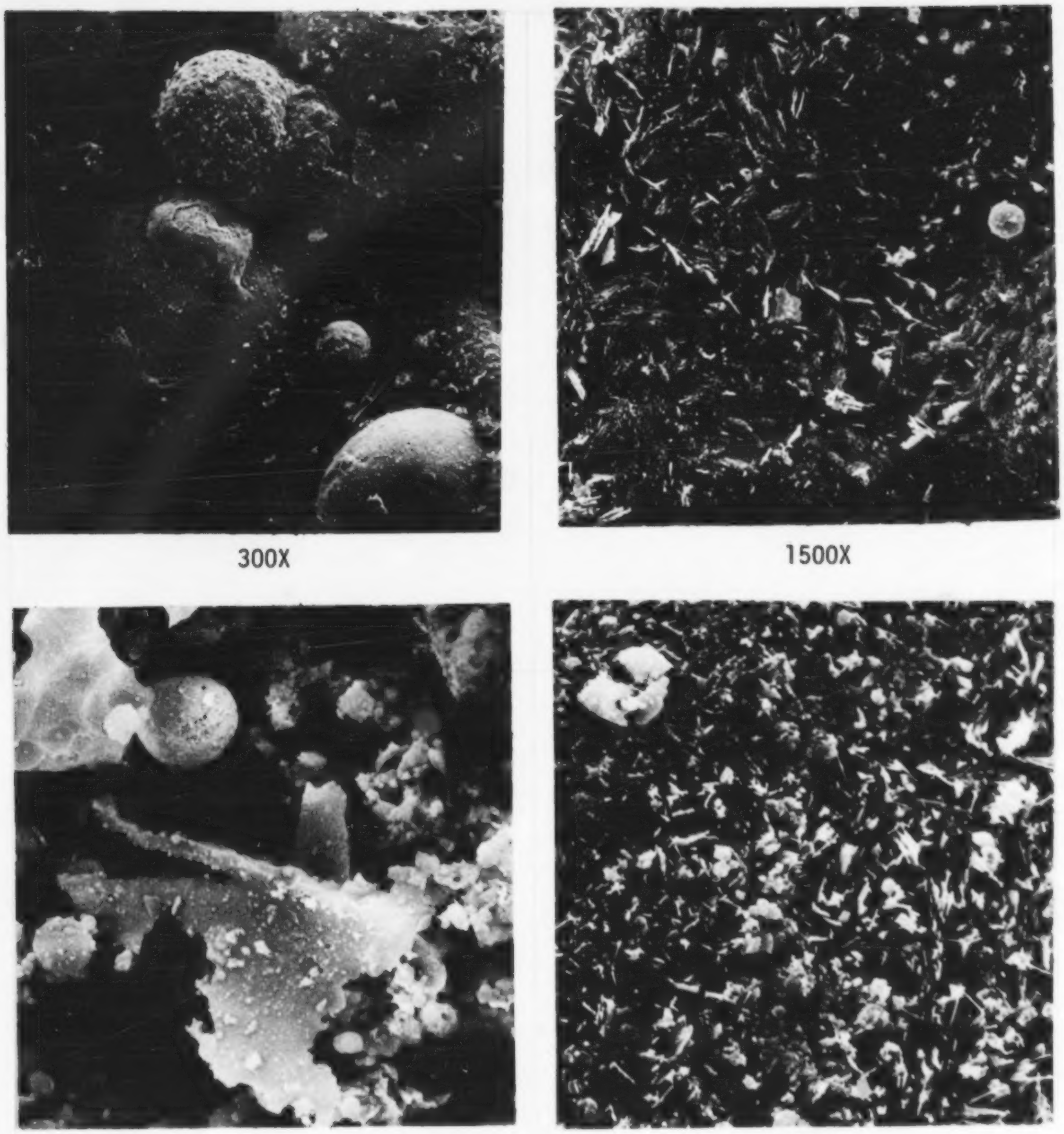
150X

300X

600X

1500X

Figure 17 SEM Photomicrographs of Slag Accumulated on Screen Tubes While Firing Coal A (Outer surface)



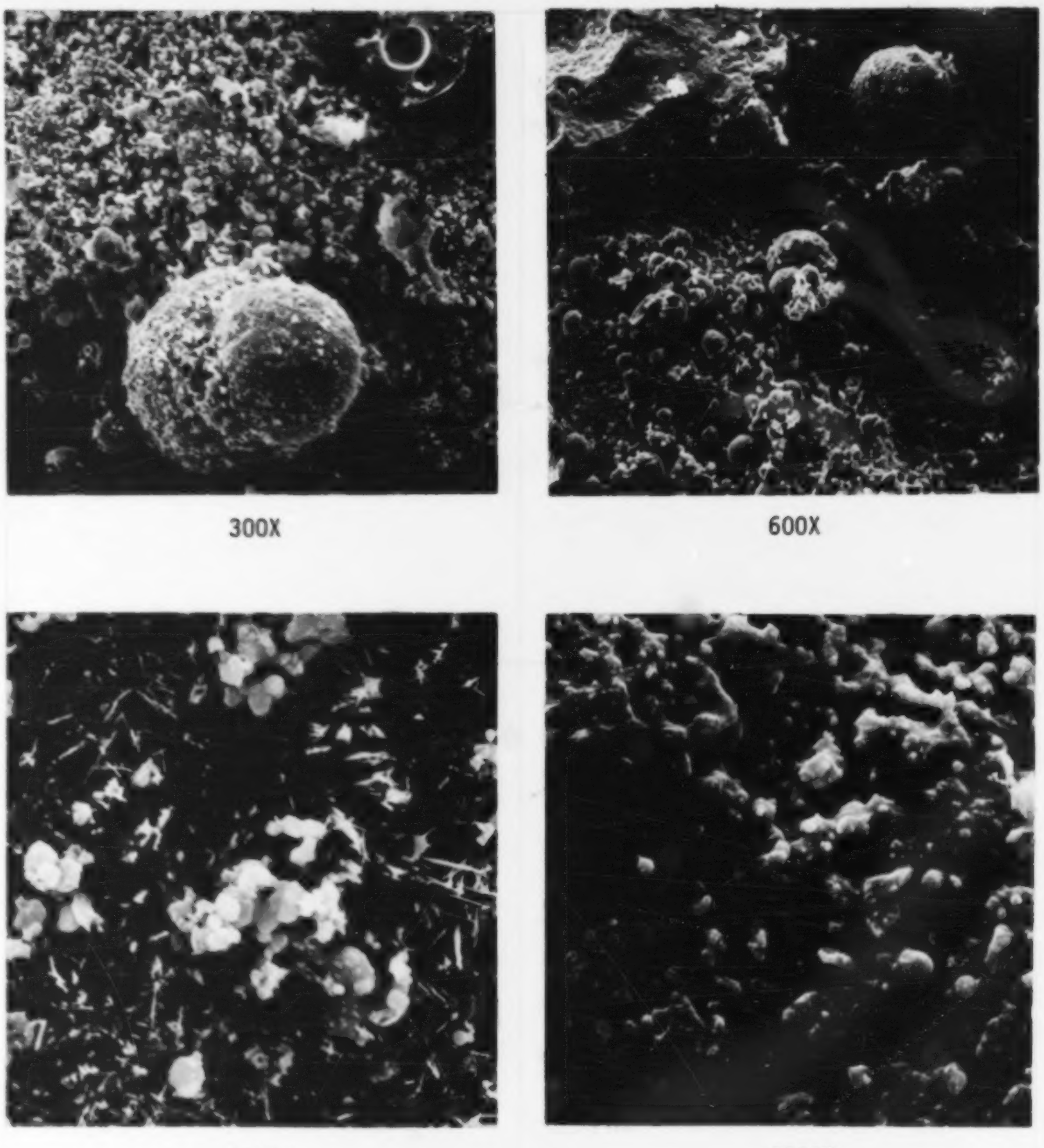
300X

1500X

1500X

3000X

Figure 18 SEM Photomicrographs of Slag Accumulated on Screen Tubes While Firing Coal A (Inner surface)



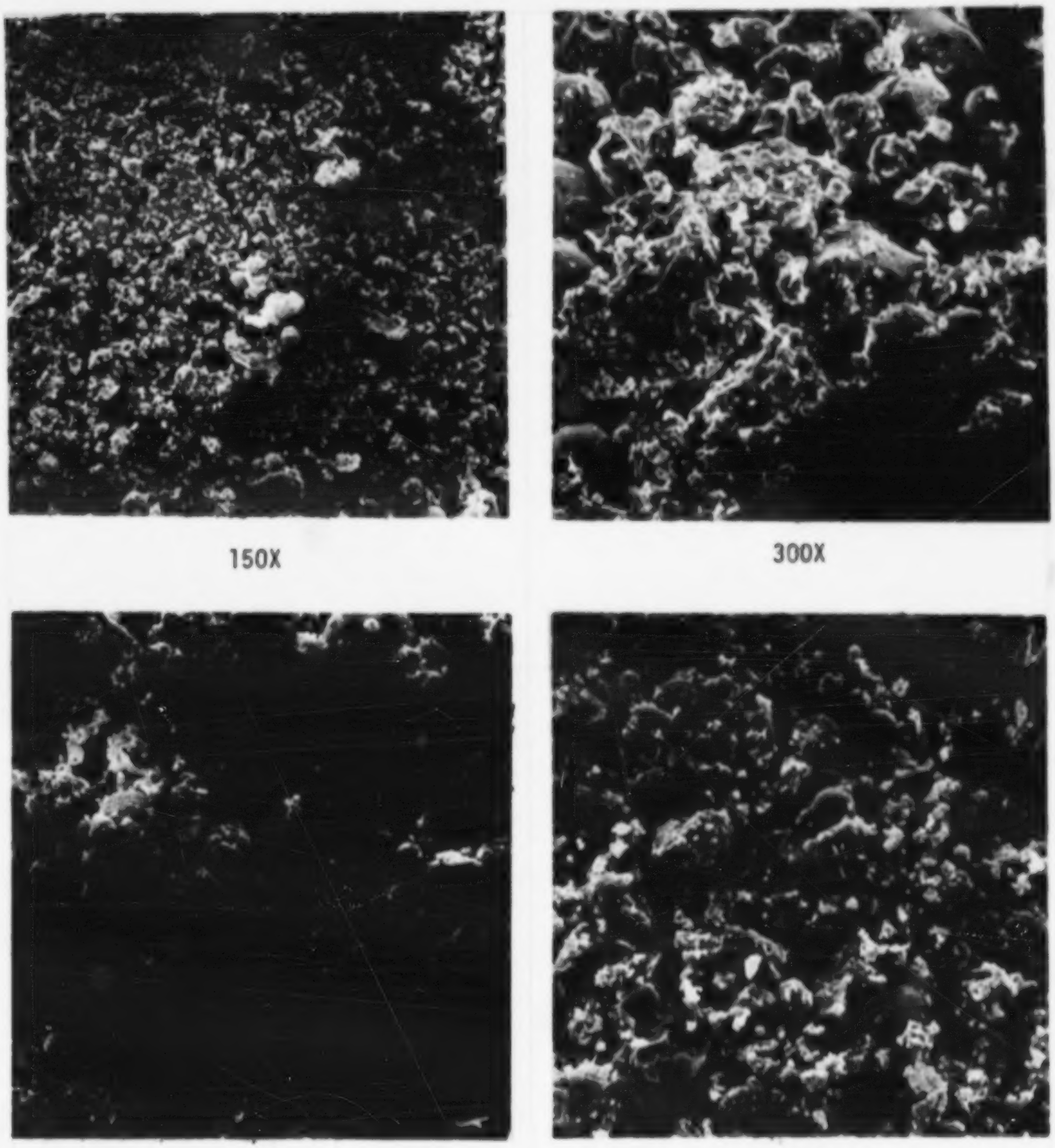
300X

600X

1500X

3000X

Figure 19 SEM Photomicrographs of Slag Accumulated on Upper North Sidewall of Furnace While Firing Coal A (Rough outer surface)



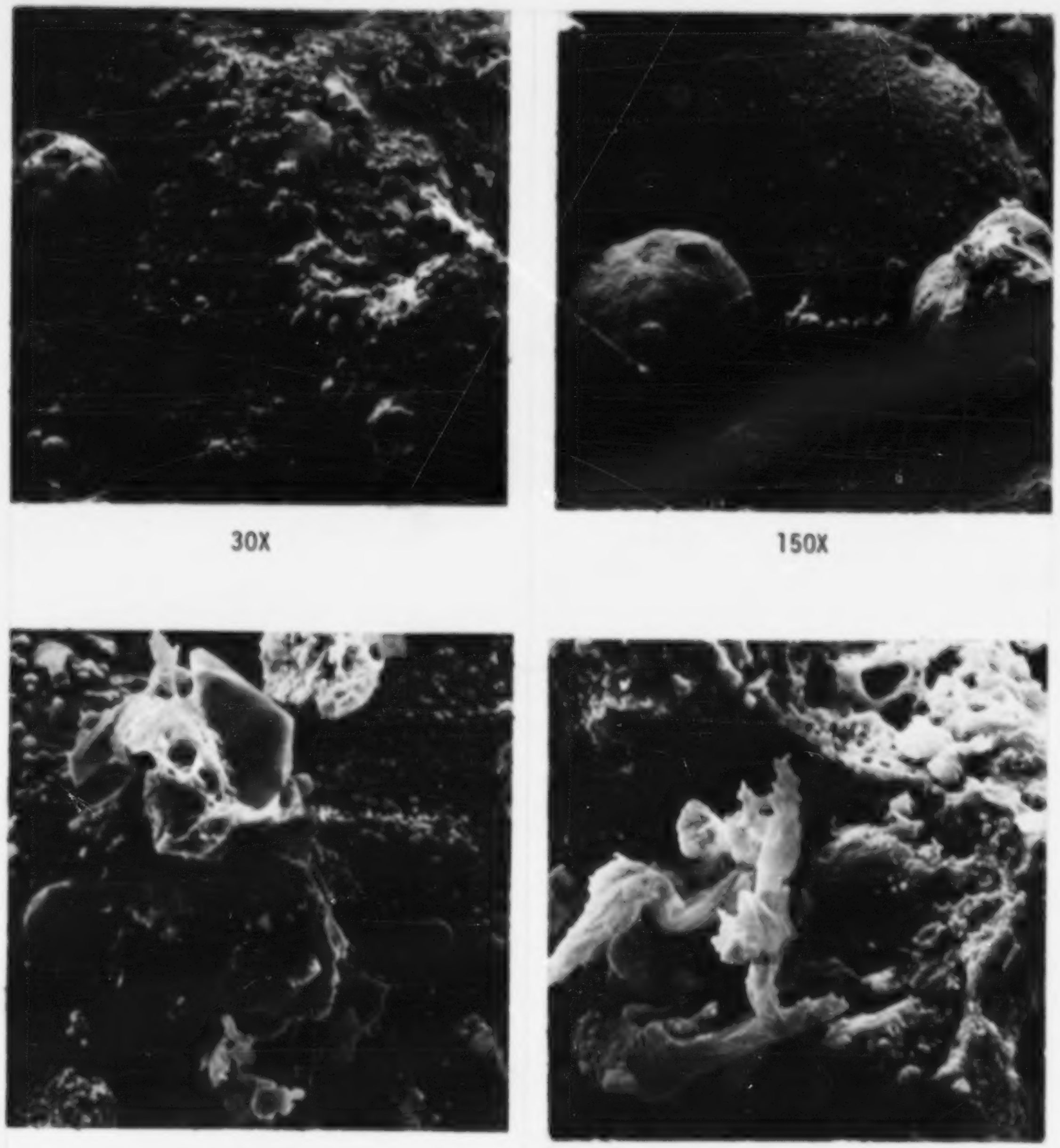
150X

300X

300X

600X

Figure 20 SEM Photomicrographs of Slag Accumulated on Upper North Sidewall of Furnace While Firing Coal A (Outer surface)



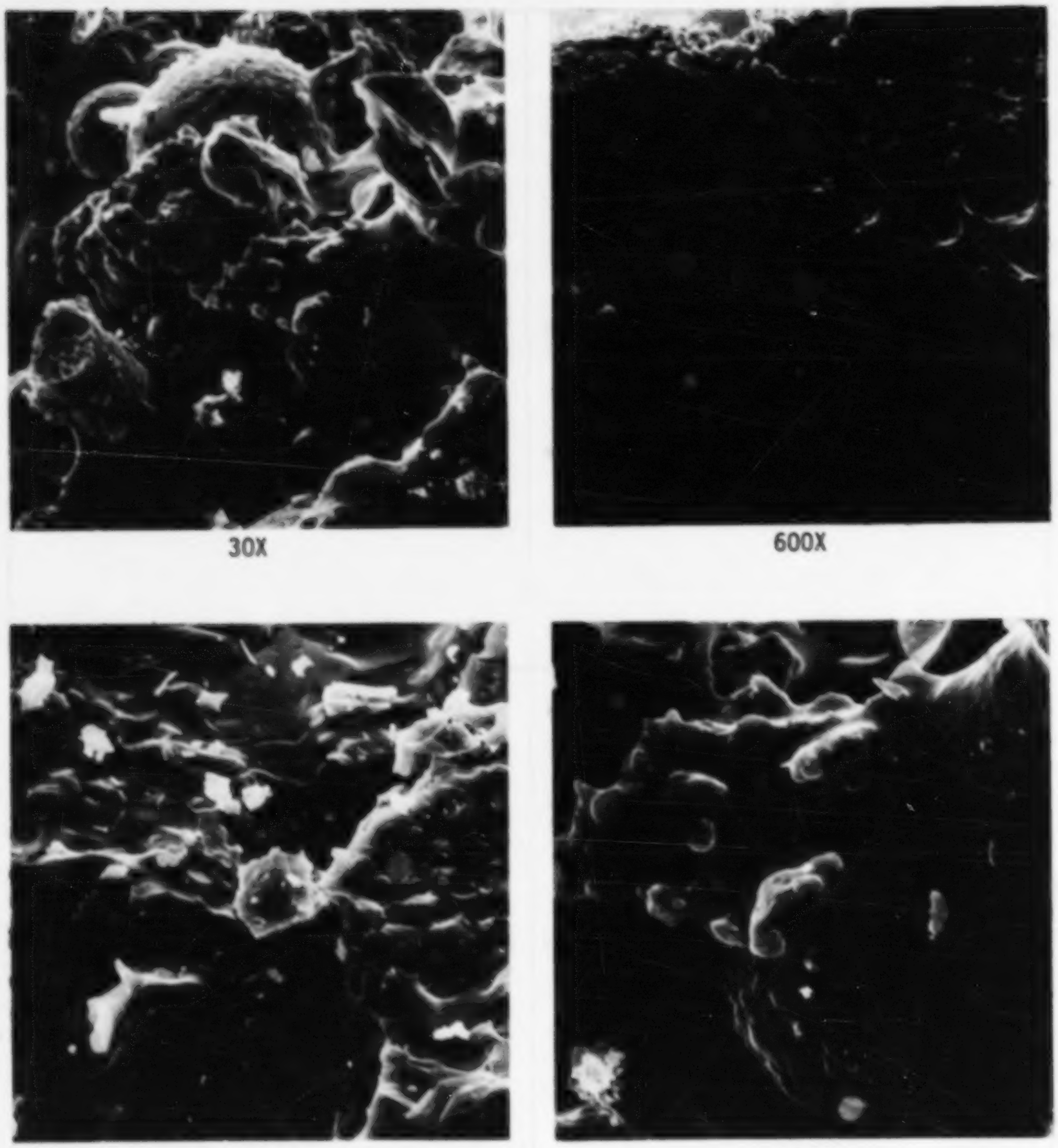
30X

150X

1200X

1500X

Figure 21 SEM Photomicrographs of Slag Accumulated on Lower North Sidewall of Furnace While Firing Coal A (Outer surface)



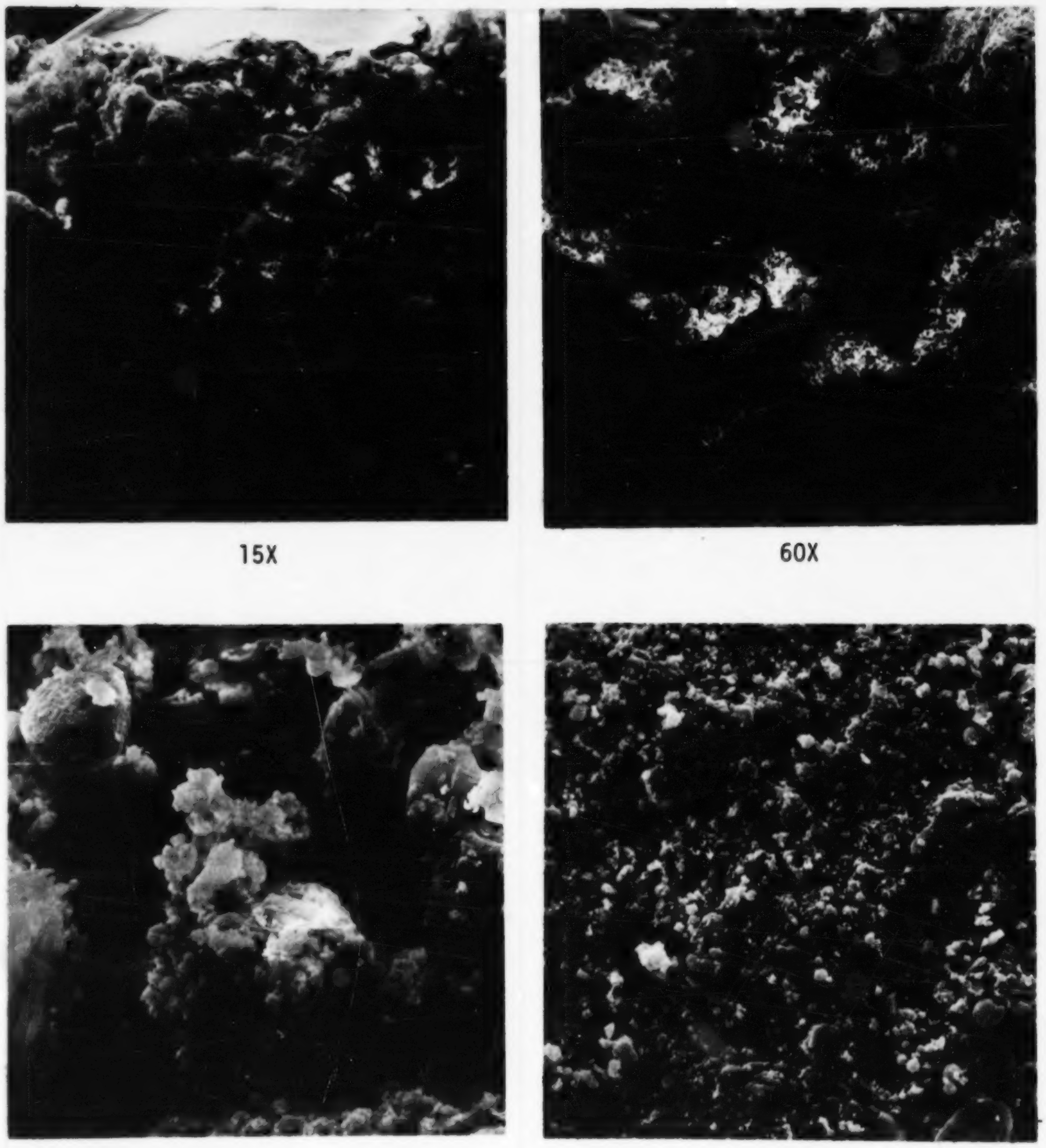
30X

600X

1500X

1500X

Figure 22 SEM Photomicrographs of Slag Accumulated on Lower North Sidewall of Furnace While Firing Coal A (Cross section)



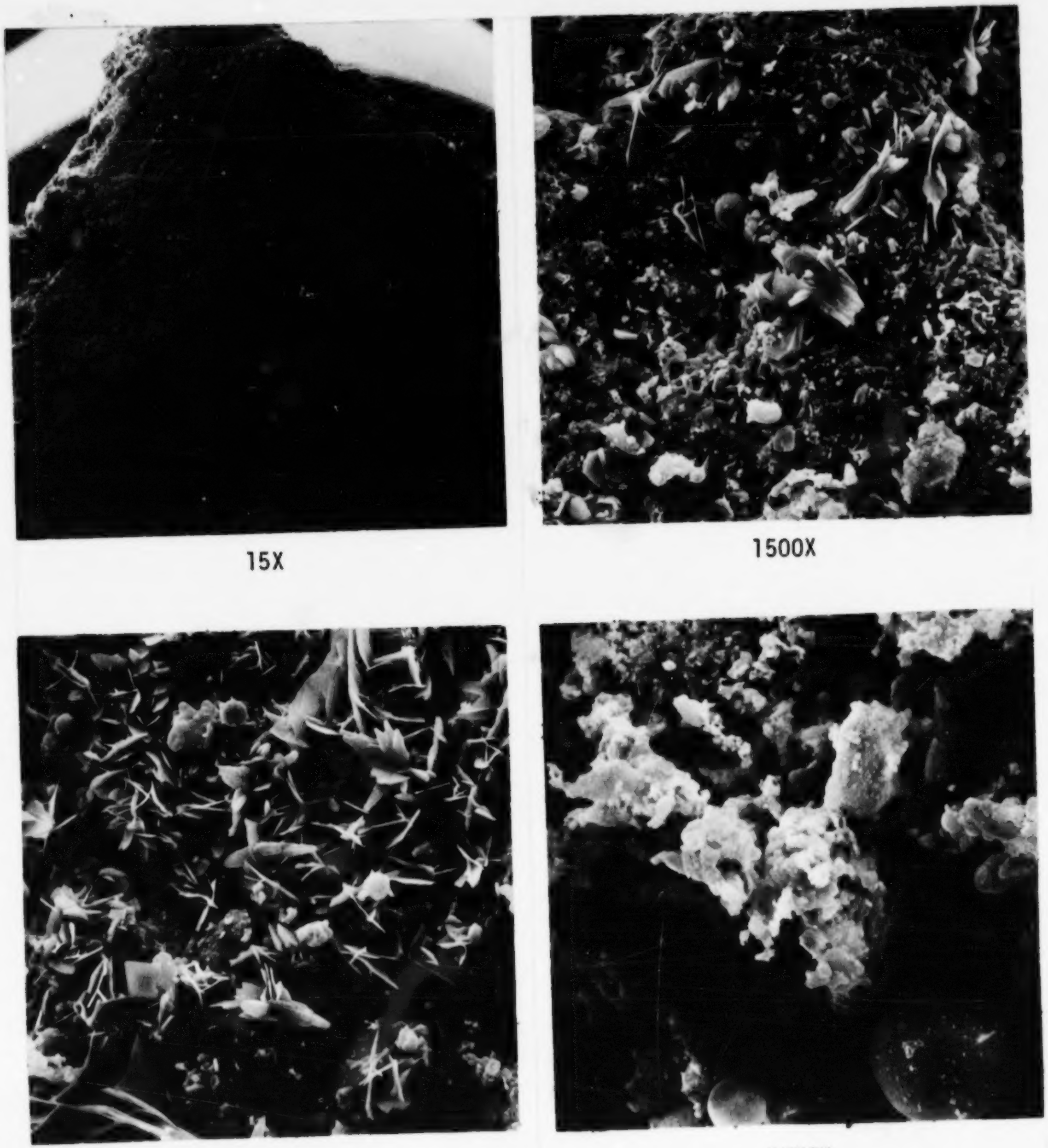
15X

60X

1500X

1500X

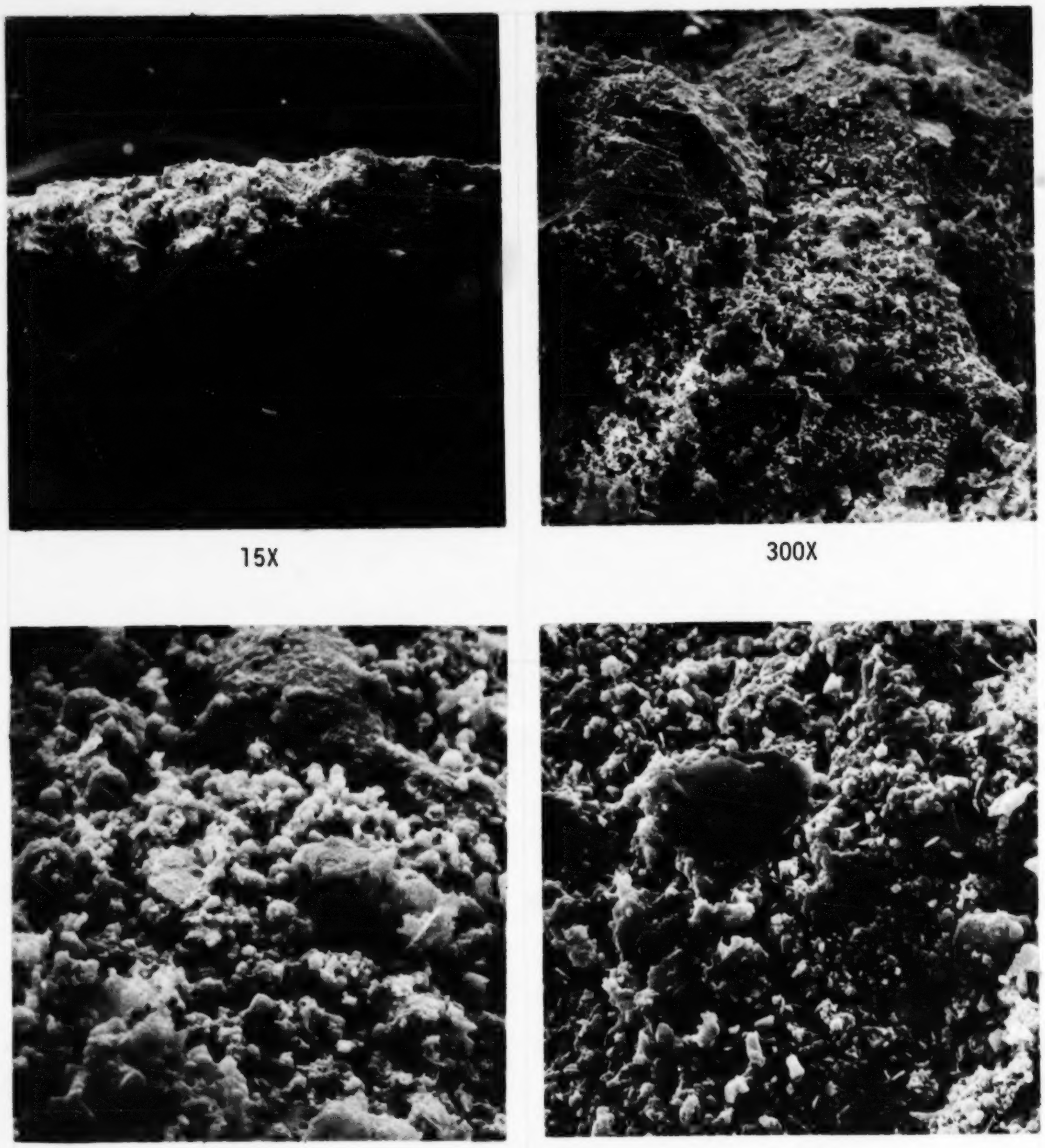
Figure 23 SEM Photomicrographs of Slag Accumulated on Screen Tubes While Firing Teledyne dRDF/Coal D Blend (Outer surface)



15X 1500X

1500X 1500X

Figure 24 SEM Photomicrographs of Slag Accumulated on Screen Tubes While Firing Teledyne dRDF/Coal D Blend (Inner surface)



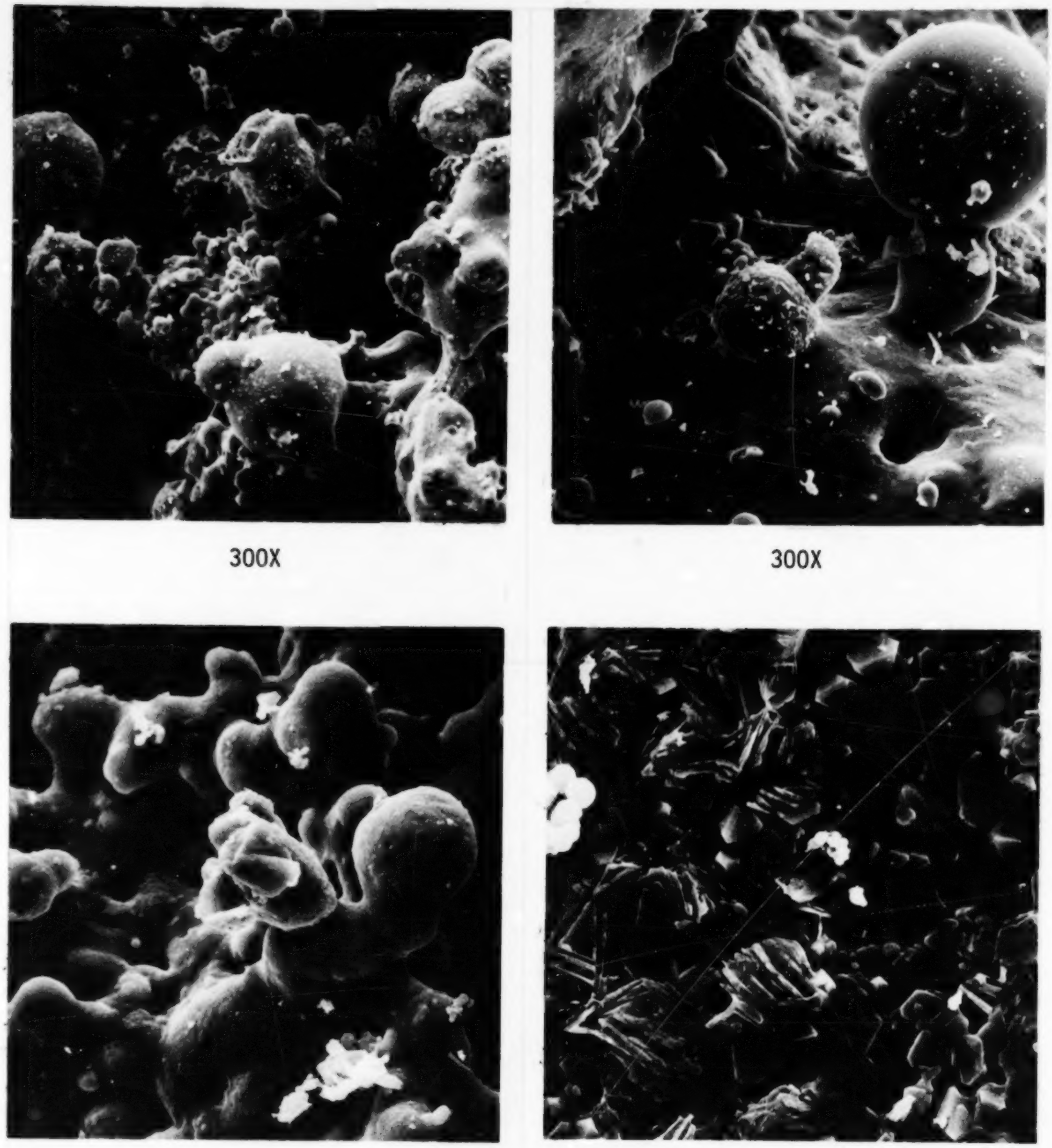
15X

300X

1500X

3000X

Figure 25 SEM Photomicrographs of Slag Accumulated on Screen Tubes While Firing Teledyne dRDF/Coal D Blend (Cross Section)



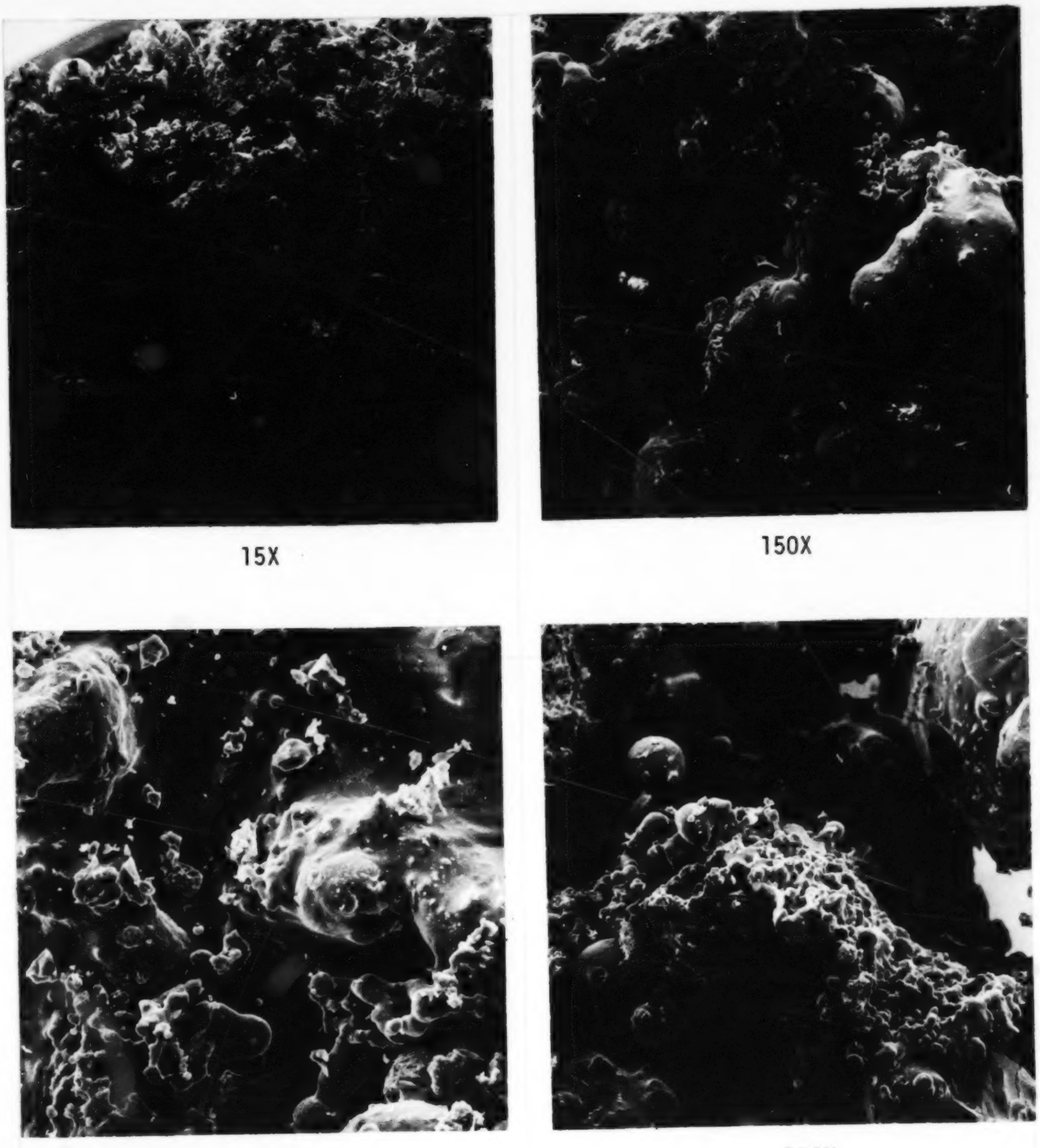
300X

300X

1500X

3000X

Figure 26 SEM Photomicrographs of Slag Accumulated on Front Wall of Furnace While Firing Teledyne dRDF/Coal D Blend (Cross Section)



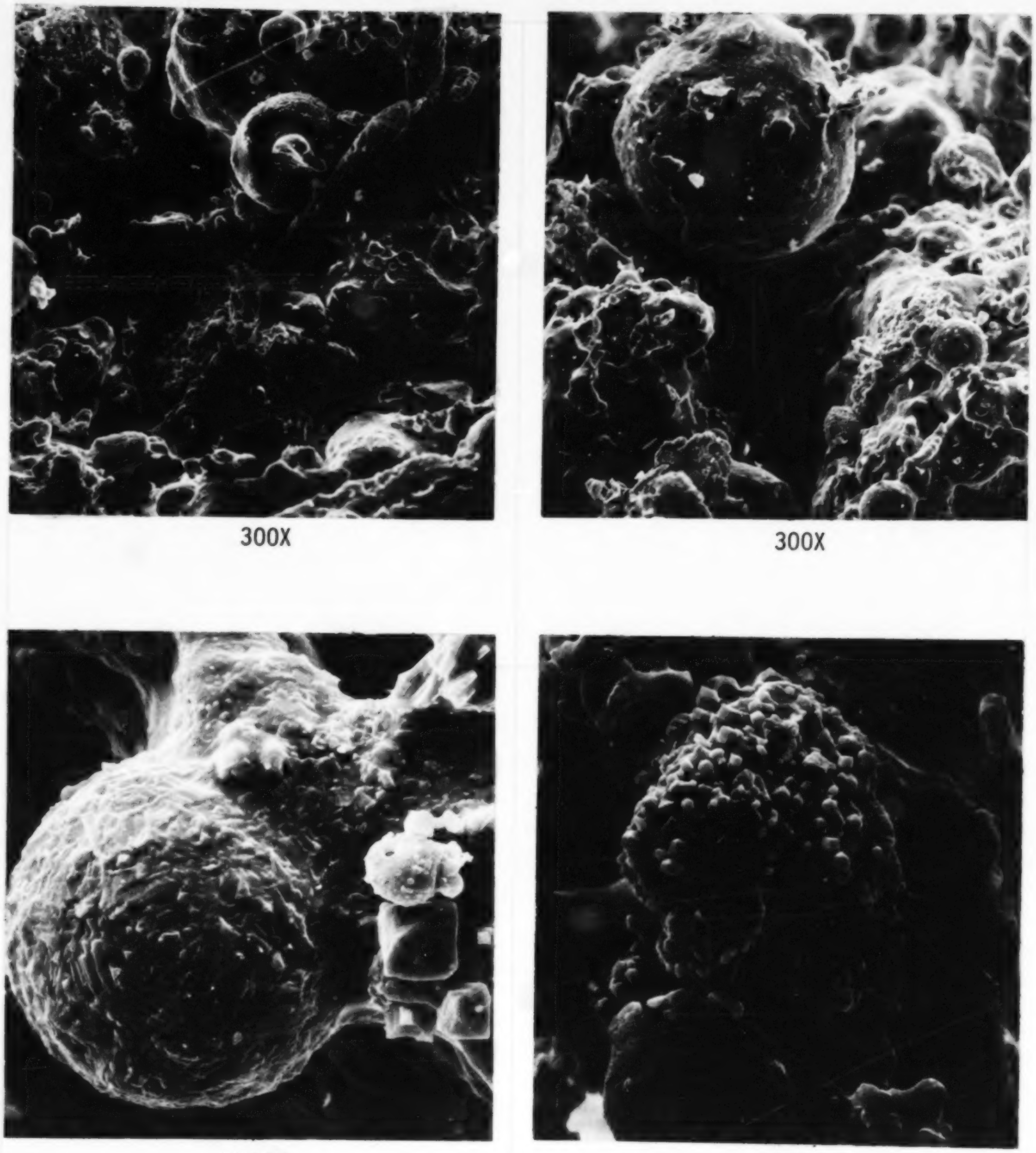
15X

150X

300X

150X

Figure 27 SEM Photomicrographs of Slag Accumulated on Lower North Sidewall of Furnace While Firing Teledyne dRDF/Coal D Blend (Cross Section)



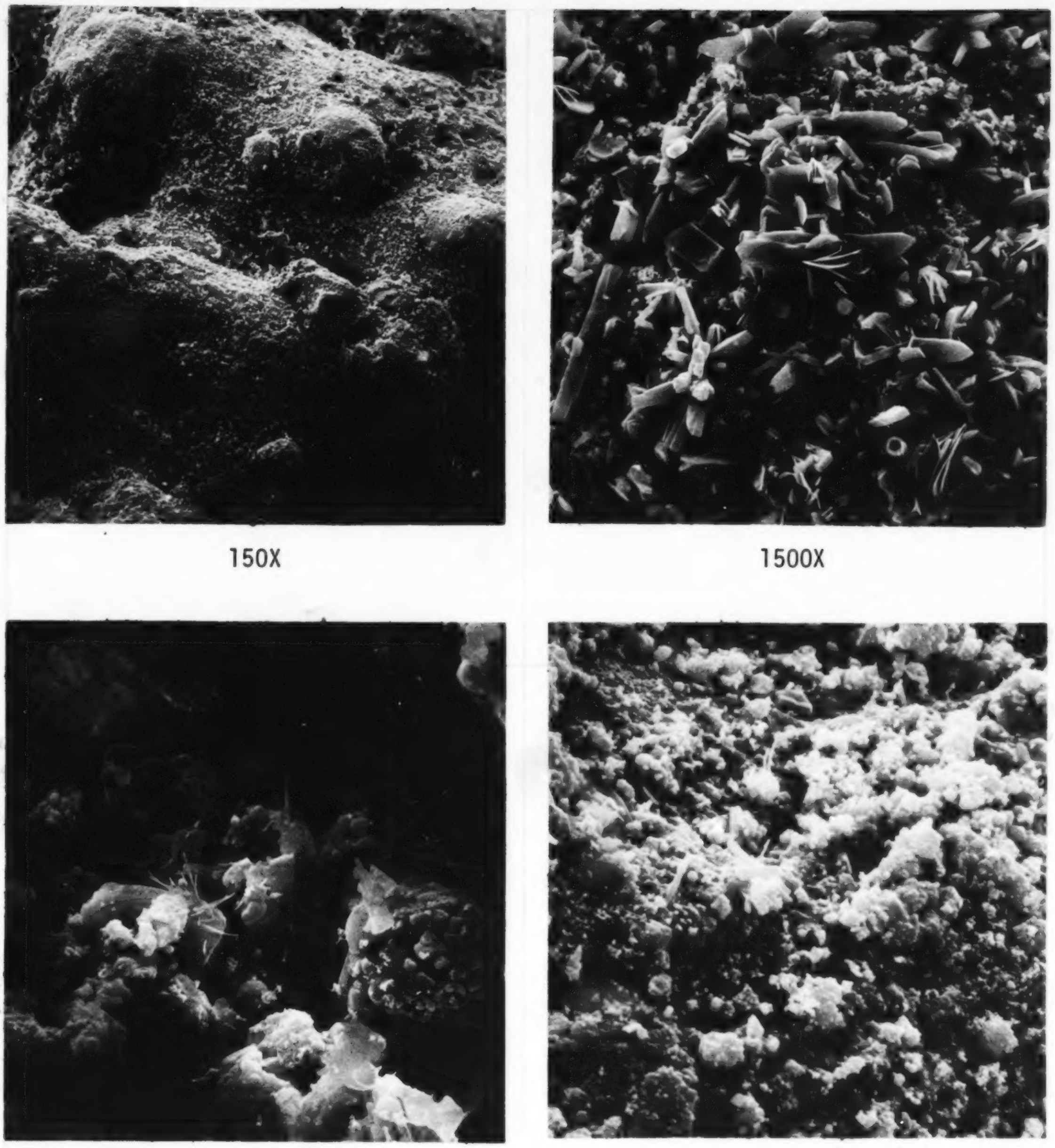
300X

300X

1500X

1500X

Figure 28 SEM Photomicrographs of Slag Accumulated on Lower South Sidewall of Furnace While Firing Teledyne dRDF/Coal D Blend (Cross section)



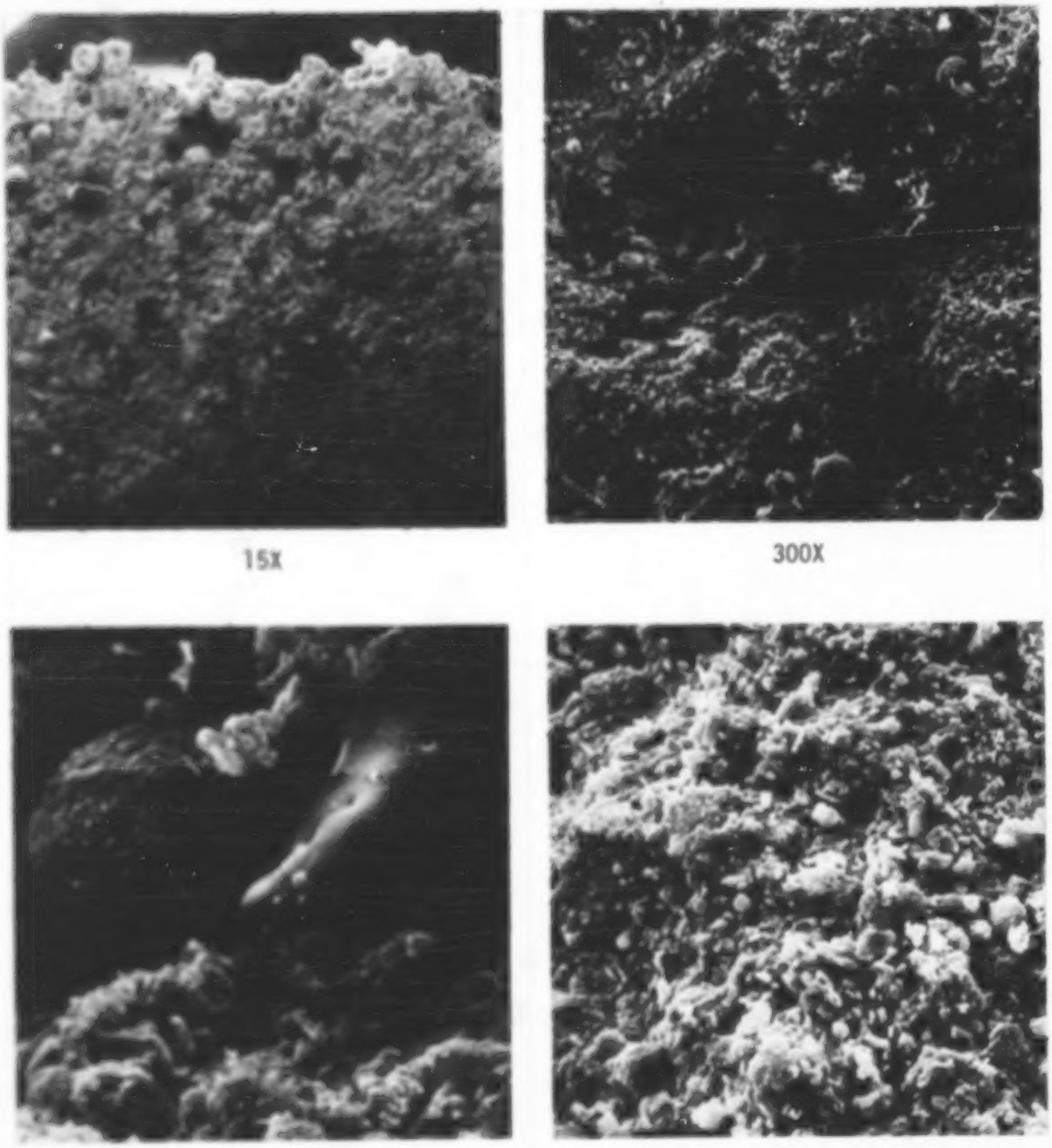
150X

1500X

3000X

3000X

Figure 29 SEM Photomicrographs of Slag Accumulated on Screen Tubes While Firing NCRR dRDF/Coal B Blend (Outer surface)



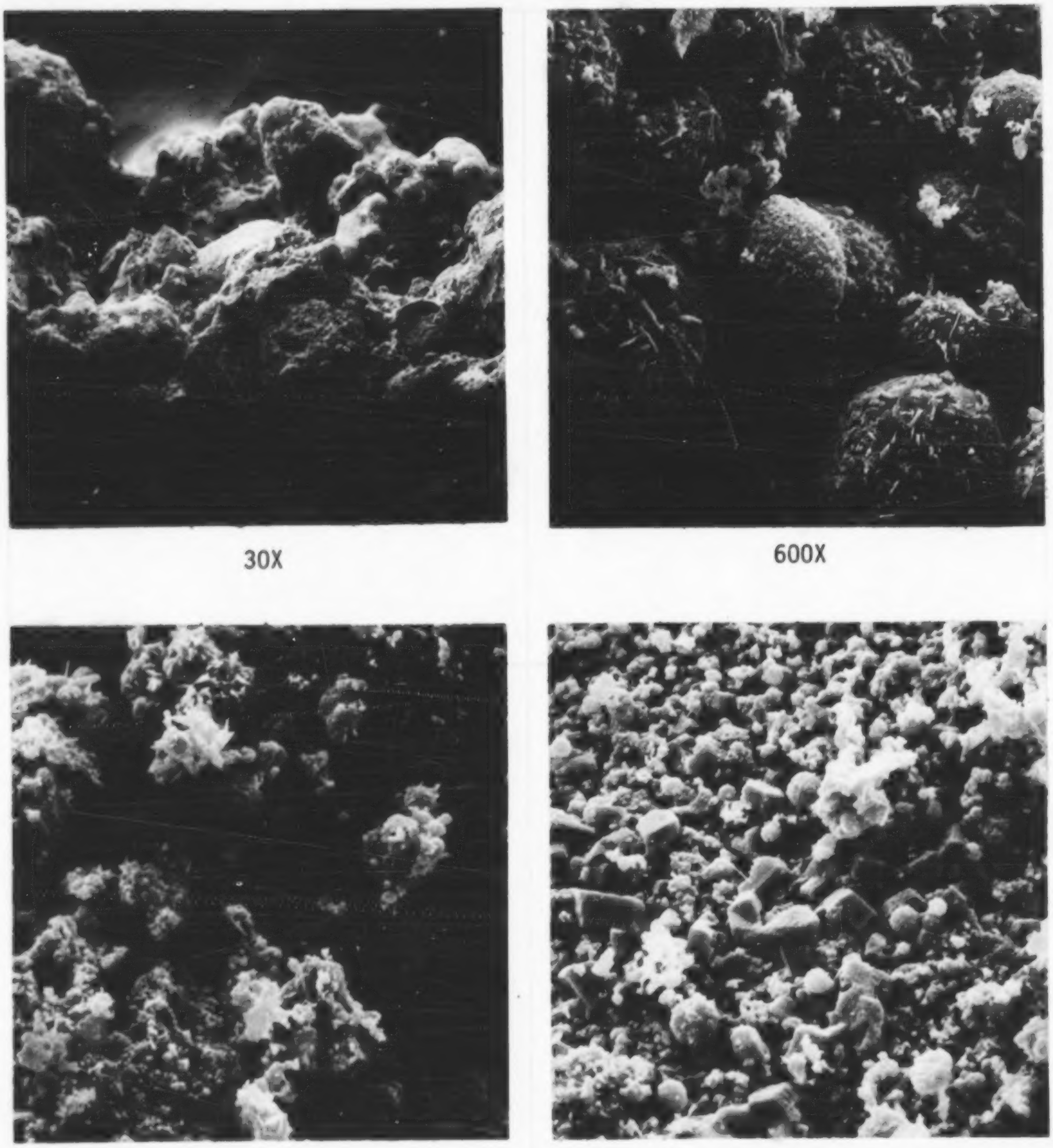
15X

300X

1500X

1500X

Figure 30 SEM Photomicrographs of Slag Accumulated on Screen Tubes While Firing NCRR dRDF/Coal B Blend (Inner Surface)



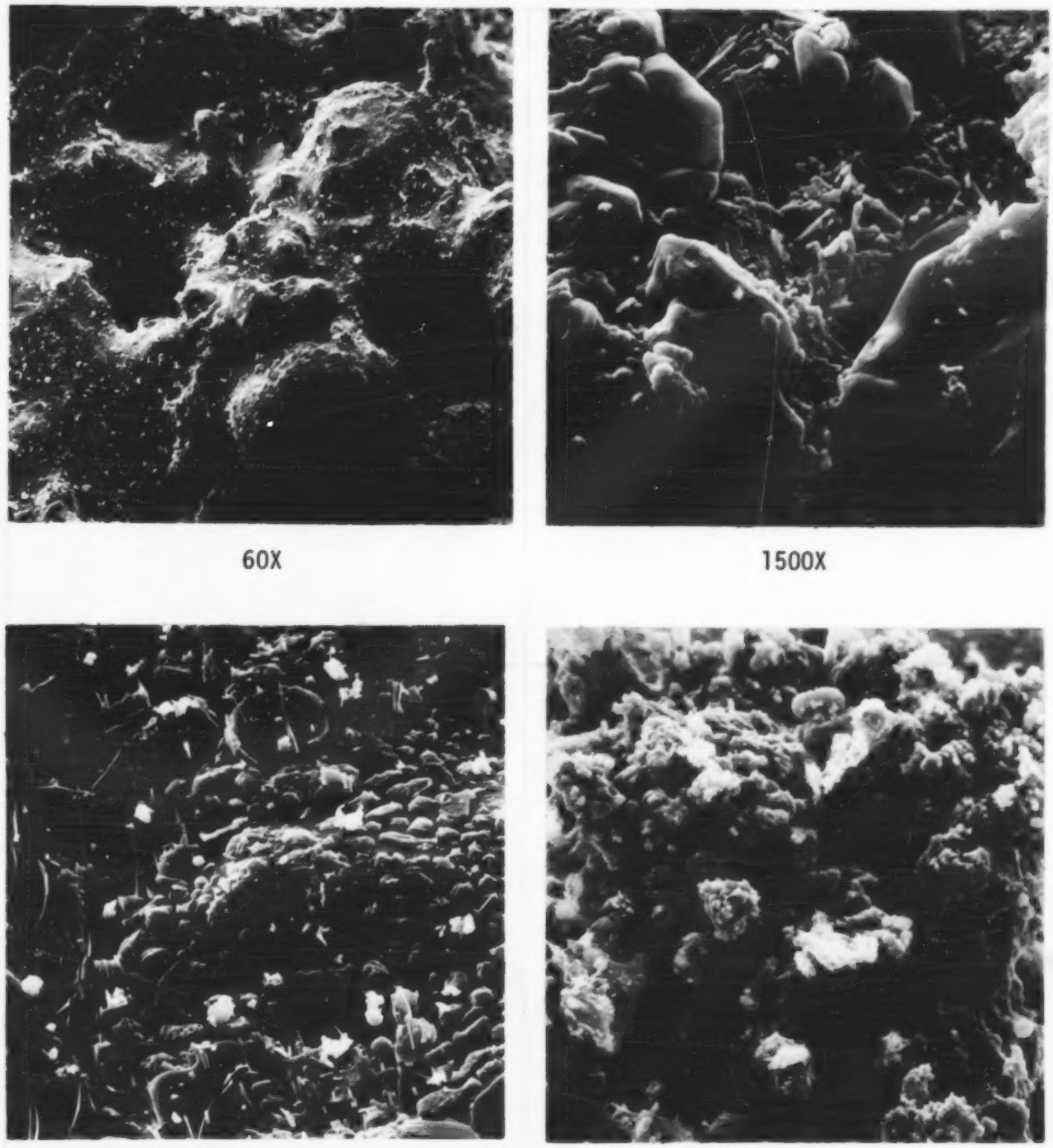
30X

600X

1500X

1500X

Figure 31 SEM Photomicrographs of Slag Accumulated on Screen Tubes While Firing NCRR dRDF/Coal B Blend (Cross section)



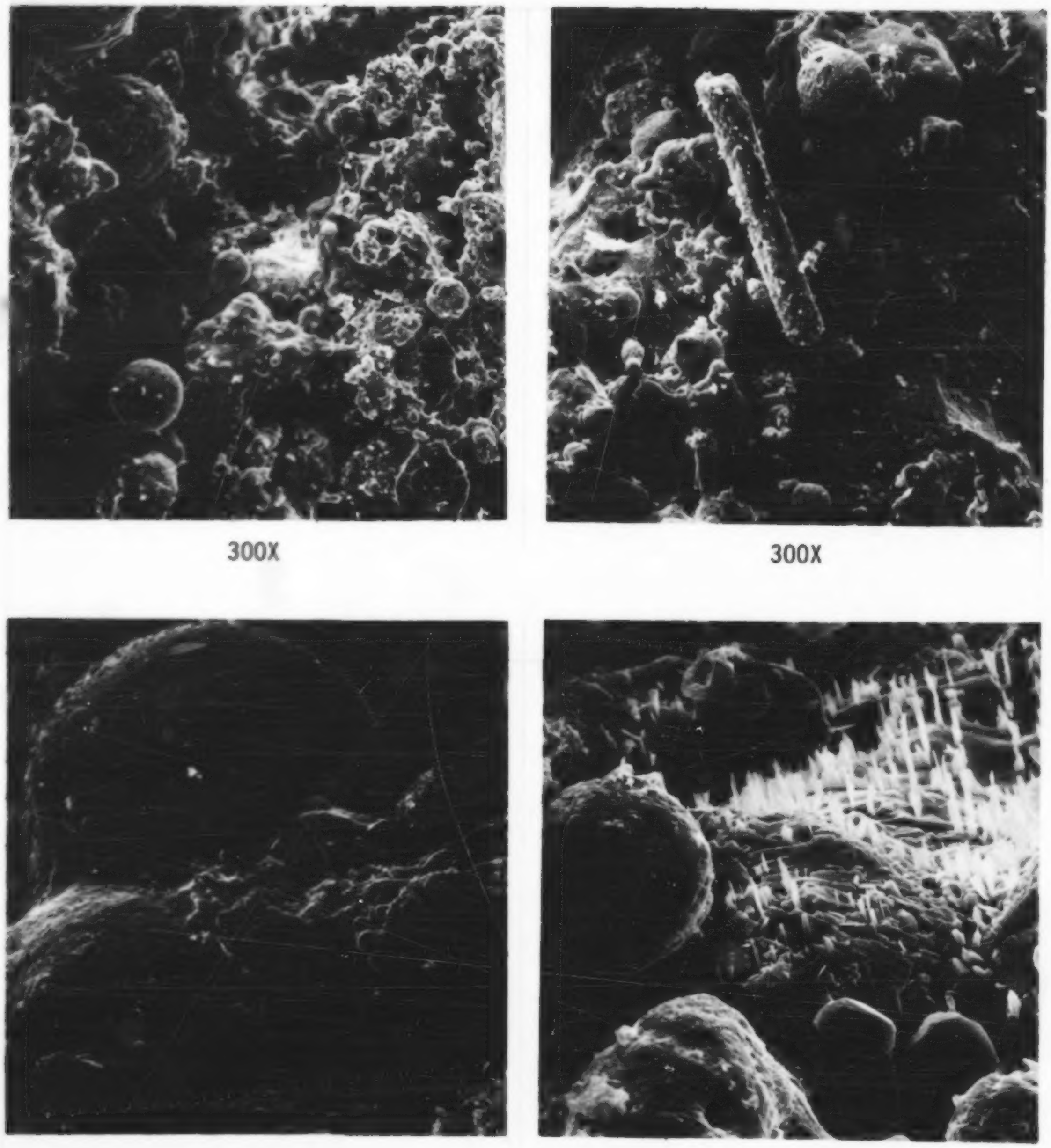
60X

1500X

1500X

3000X

Figure 32 SEM Photomicrographs of Slag Accumulated on Front Wall of Furnace While Firing NCRR dRDF/Coal B Blend



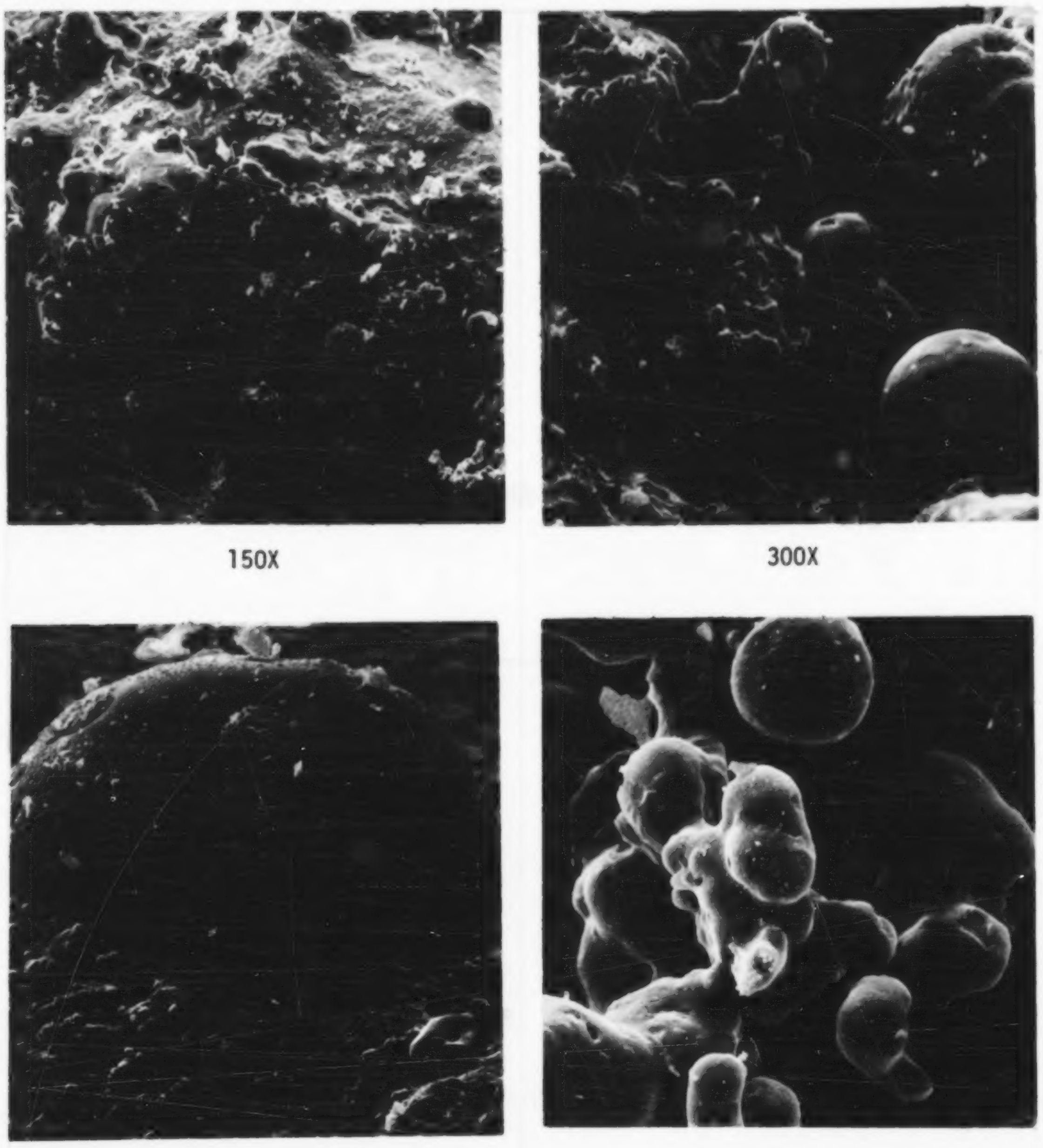
300X

300X

600X

1500X

Figure 33 SEM Photomicrographs of Slag Accumulated on Lower North Sidewall of Furnace While Firing NCRR dRDF/Coal B Blend (Inner surface)



150X

300X

1500X

1500X

Figure 34 SEM Photomicrographs of Slag Accumulated on Upper North Sidewall of Furnace While Firing NCRR dRDF/Coal B Blend (Inner surface)

chemical analysis, we can conclude that the matrix containing the particulate material is a low-temperature mixture of Al_2O_3, SiO_2, FeS, FeO, and sulfur. The sulfur is probably released once the deposit is formed. The particulate material is most likely Fe_2O_3. It would be desirable to extend the scope of the program to confirm this theory by means of the nondispersive x-ray. The deposits formed in the upper reaches of the furnace while firing dRDF show signs of a crystalline structure. The crystals are probably the result of condensation of sulfates of sodium, calcium, or potassium. In general, the particulates collected when firing dRDF appear to be smaller. Occasional large particles found in the deposit appear to be agglomerates. Photomacrographs (Figures 35 through 39) suggest the deposits formed by coal are denser than those formed with dRDF. There is a smaller deposit formed when firing the blended fuel than when firing coal alone--an indication that less ash is depositing on tube surfaces.

CORROSION STUDIES

Carbon steel and Type 304SS were exposed to seven different ash samples placed in individual crucibles at 550 and 750°F. Low alloy 2-1/4%Cr-1%Mo and Type 304SS were exposed to the same ash at 950°F. The various alloys were selected to simulate the material of construction for commercial boilers, and the Type 304SS was used as a comparison alloy at all three temperatures. The coupons measured approximately 1 in. x 1.3 in. x 1/8 in. for the carbon steel and Type 304SS and 1 in. x 1.3 in. x 1/4 in. for the 2-1/4%Cr-1%Mo steel. The corresponding weights were approximately 15 to 16 grams with a carbon steel and Type 304SS and approximately 35 to 38 grams for the 2-1/4%Cr-1%Mo specimens.

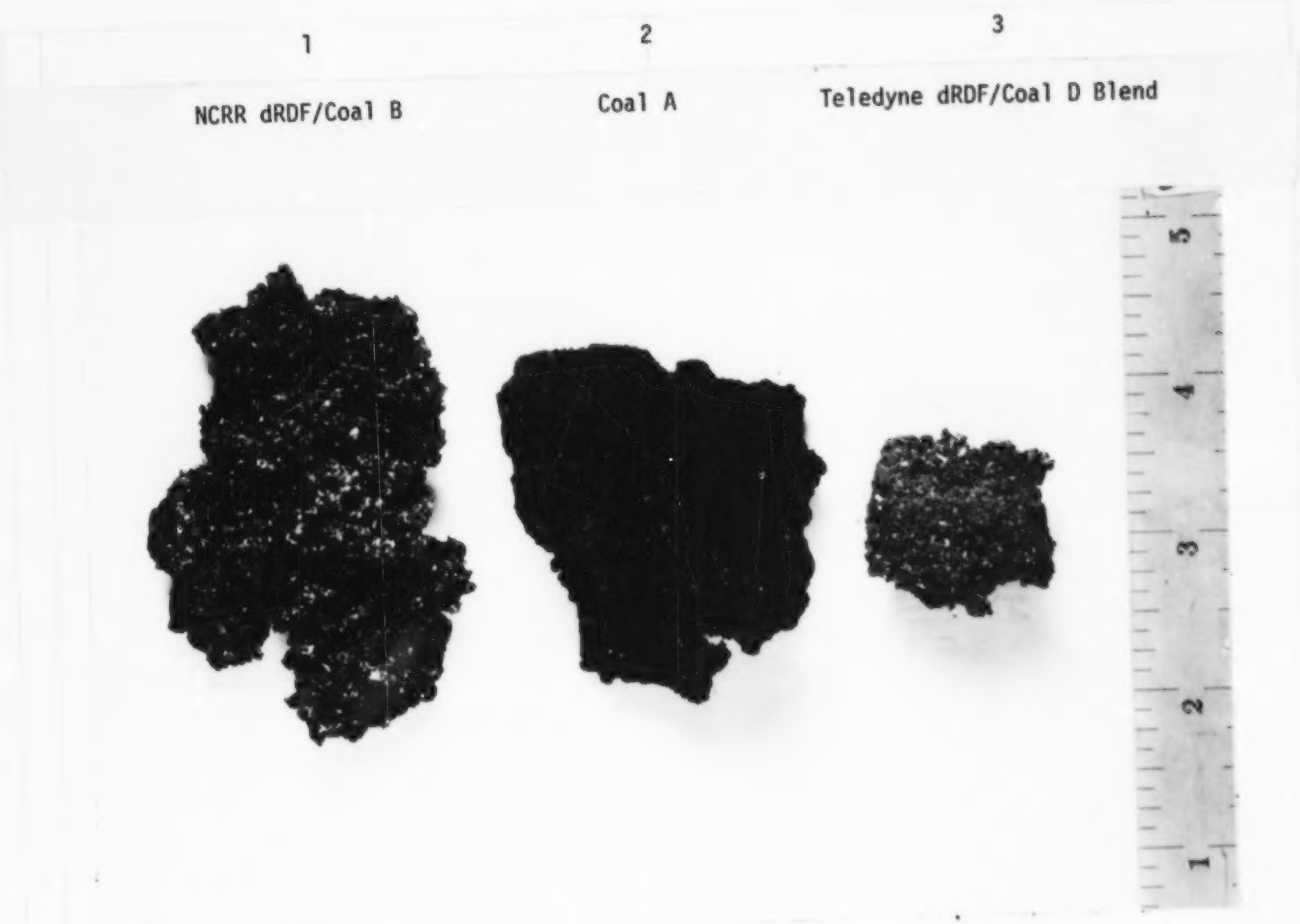

1
NCRR dRDF/Coal B
2
Coal A
3
Teledyne dRDF/Coal D Blend
5
4
3
2
1

Figure 35 Photomacrographs of Slag Samples Taken From the Front Wall (1), Lower North Sidewall (2), and Lower South Sidewall (3) of Furnace

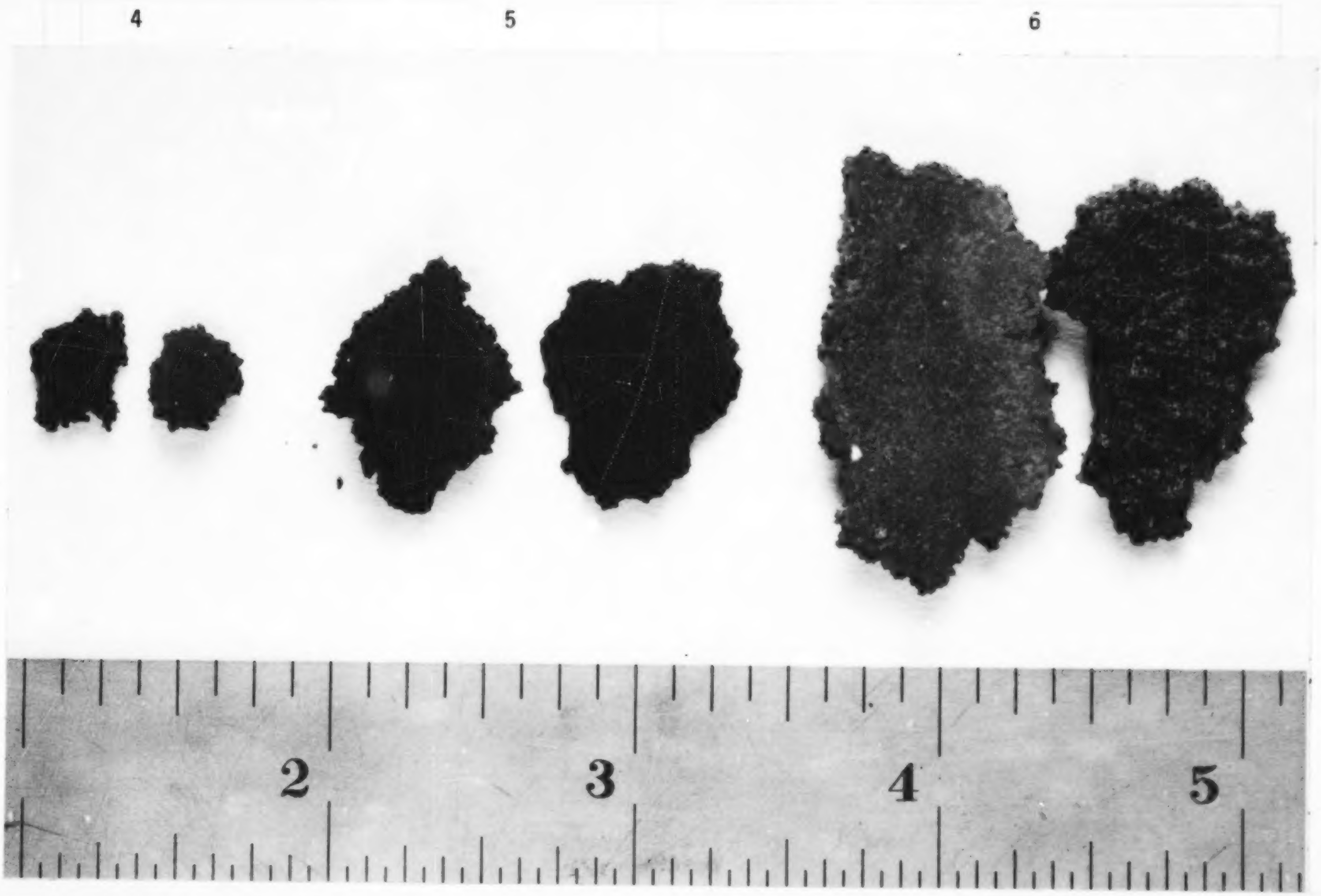


Figure 36 Photomacrographs of Slag Samples Taken From Screen Tubes While Firing NCRR dRDF/ Coal B Blend (4), Coal A (5), and Teledyne dRDF/Coal D Blend (6)

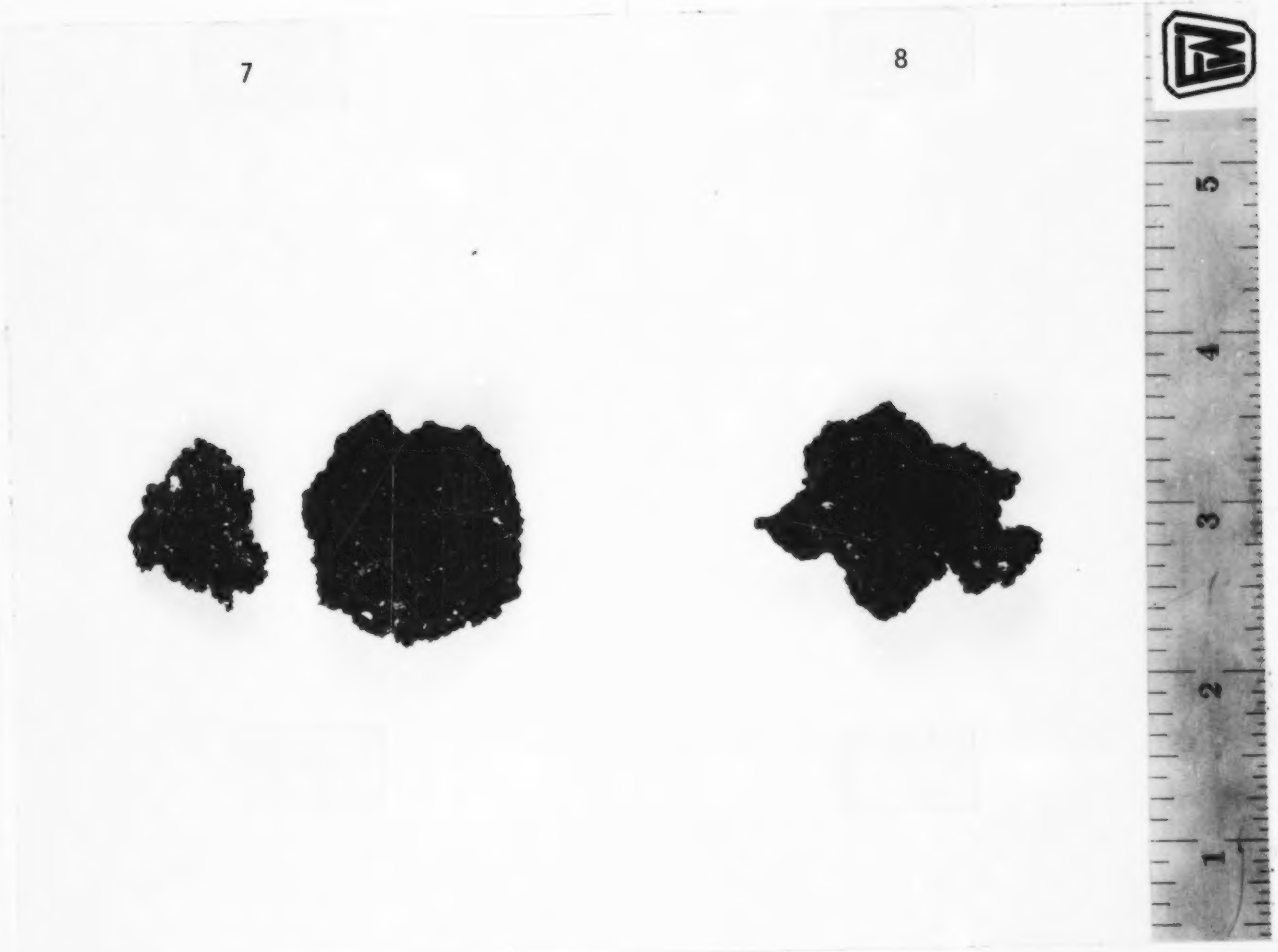


Figure 37 Photomacrographs of Slag Samples Taken From Lower North Sidewall (7) and Upper North Sidewall (8) of Furnace While Firing NCRR dRDF/Coal B Blend

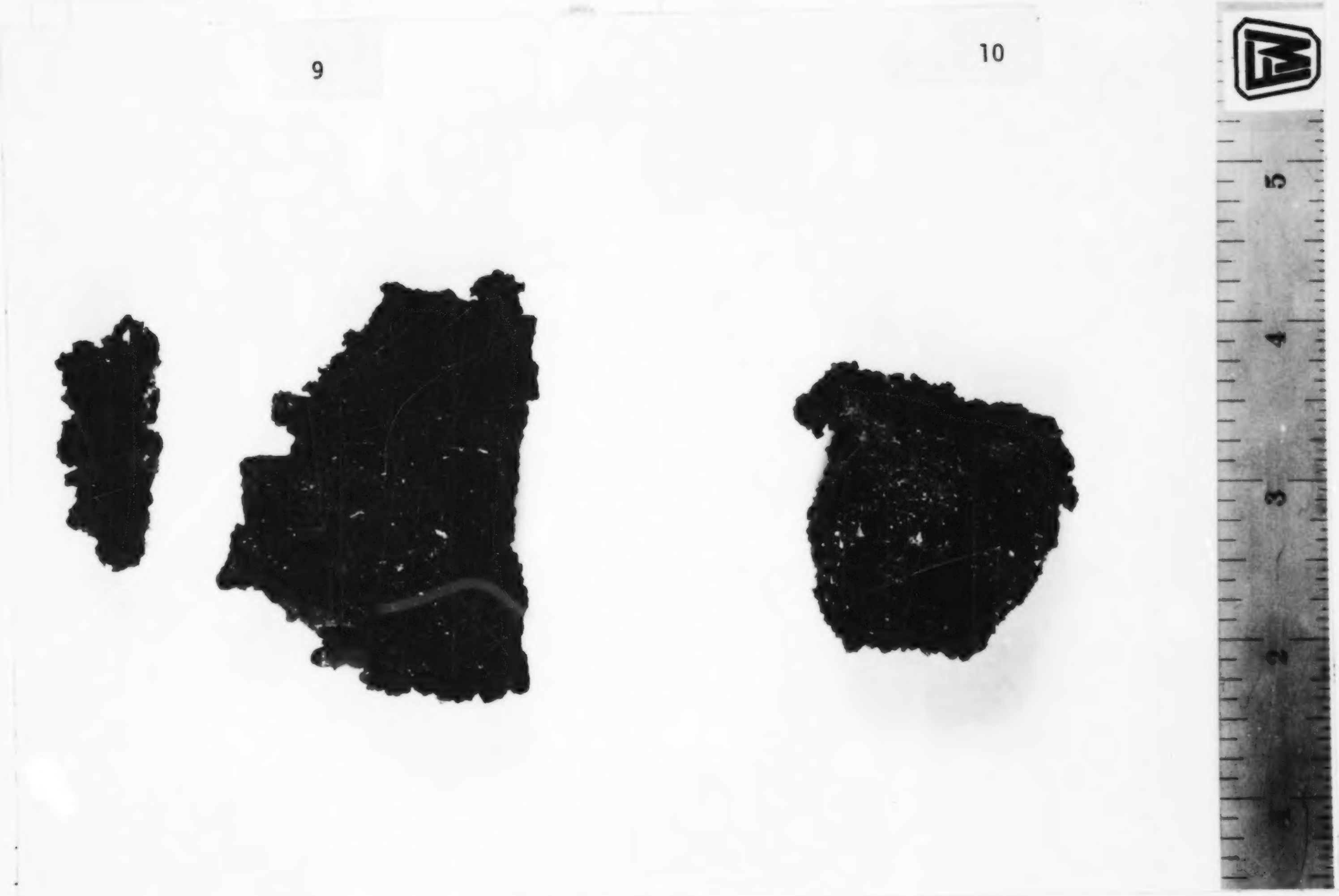


Figure 38 Photomacrographs of Slag Taken From Lower North Sidewall (9) and Front Wall (10) of Furnace While Firing Teledyne dRDF/Coal D Blend

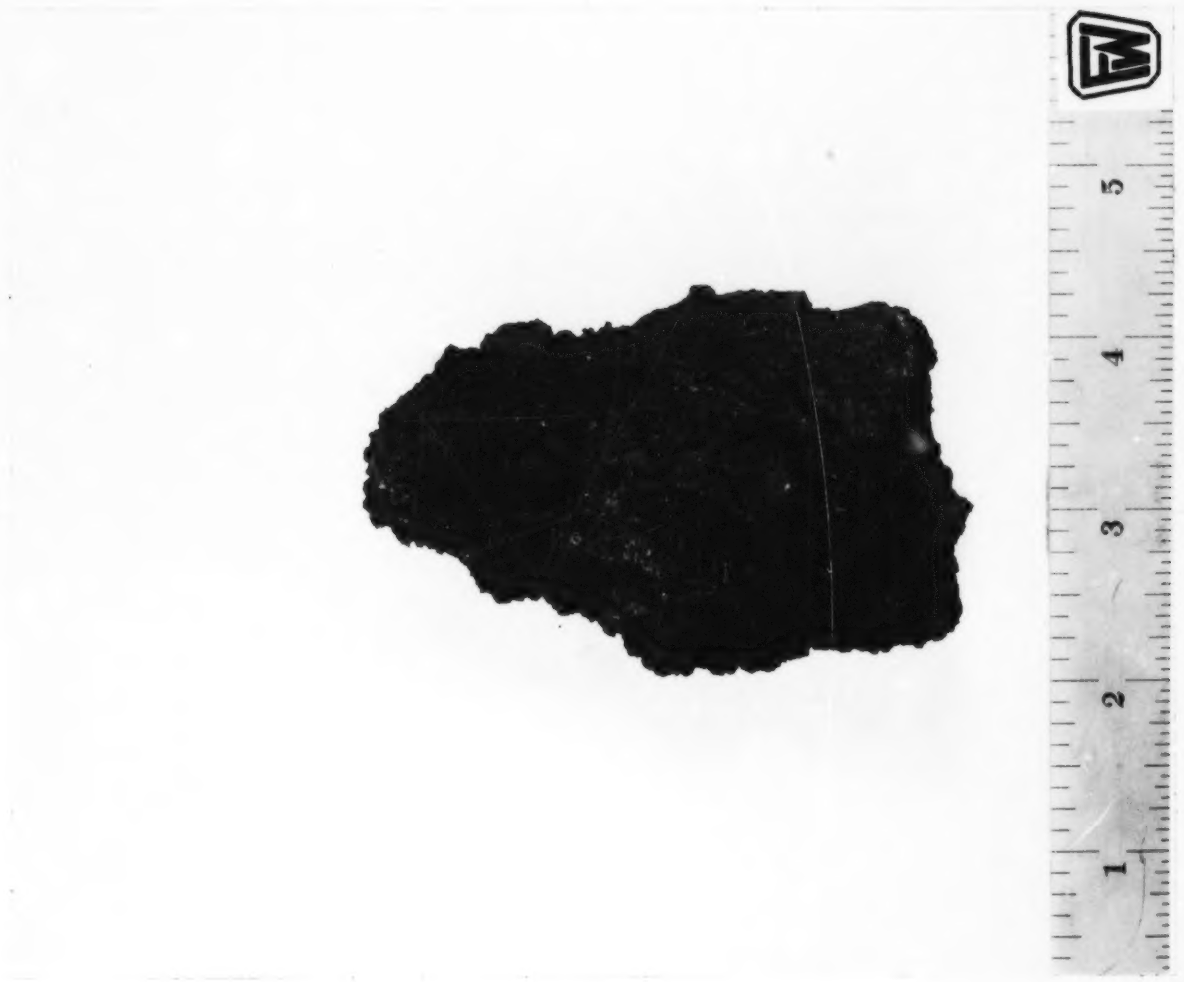


Figure 39 Photomacrograph of Slag Taken From Upper North Sidewall of Furnace While Firing Coal A

In each case the specimen had approximately one-half to three-quarters of its 2.8 in^2 surface area submerged in the ash; the remaining one-quarter to one-half was exposed to the atmosphere.

Seven crucibles were placed inside a metal box (Figure 40). In each of the three furnaces used to perform the corrosion tests at 550, 750, and 950°F, a continuous air purge was used to ensure that the specimens were continually exposed to an oxidizing environment. Each of the furnaces was held for 98 hours at the designated temperature.

After 98 hours, the coupons were descaled using the descaling procedures described in Table 5. Following descaling the coupons were reweighed, and weight losses were calculated as shown in Table 6 and Figure 41. The weight losses of the specimens in contact with the ash did not deviate significantly at 550 or 750°F from those of the material of the same type exposed to air alone. At 950°F the same was true--except for specimens exposed to ash from the screen and upper north tubes during Coal A only and the screen tubes during the Teledyne dRDF/Coal D Blend burns. These specimens exhibited a weight loss which was significantly higher than the others exposed to deposits at 950°F. This higher weight loss when converted to a corrosion rate of 36 to 56 mil/yr is not an exorbitant rate for a short time exposure. [The corrosion rate is usually higher at first as the corrosion product (oxide) forms, and reduces with longer exposure.] Also the visual appearance of the specimen did not indicate any pitting or extremely accelerated corrosion mechanism.

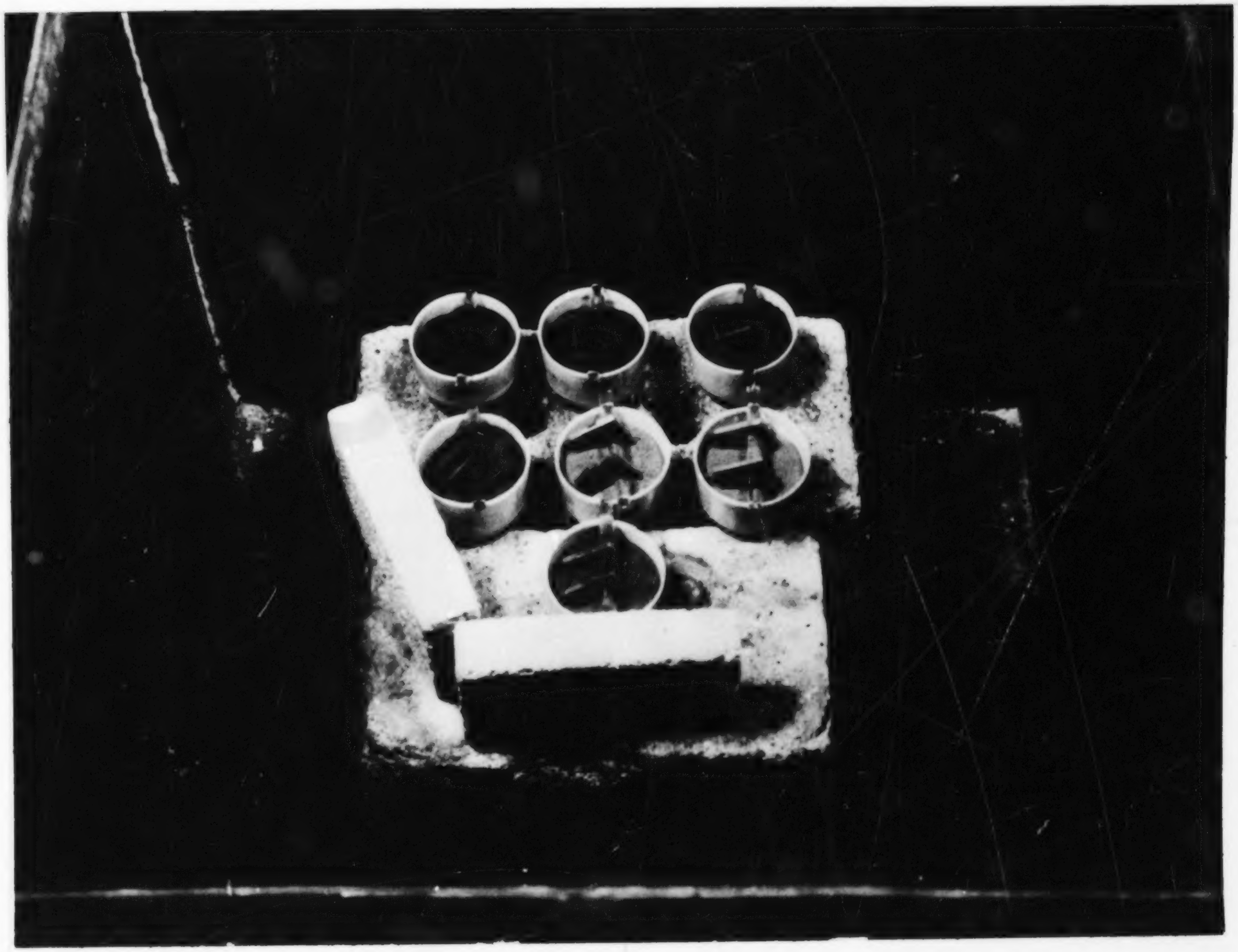


Figure 40 Carbon Steel and Type 304SS Specimens Exposed to Seven Ash Samples in Individual Crucibles

Table 5 Summary of Descaling Conditions

Material	Description	Immersion Time
304SS	Pumice scrubbed followed by immersion in 10% HNO_3 distilled water solution at 150°F for varying periods of time; pumiced again as required.	
Carbon Steel 2-1/4%Cr-1%Mo	Pumice scrubbed followed by immersion in 18% inhibited HCL solution at 140°F for several minutes; pumiced again as required.	1 to 3 minutes

Table 6 Coupon Data

Environment	Coupon No.	Material	Before Exposure				After Exposure		Total Weight Loss	Temperature (°F)
			Length (in.)	Width (in.)	Thickness (in.)	Weight (g)	Weight (g)	Thickness (in.)		
11S	1	304SS	1.336	0.890	0.120	17.039	17.043	0.120	0.004*	550
11S	2	304SS	1.386	0.905	0.120	17.949	17.936	0.120	0.013	750
11LR	3	304SS	1.302	0.851	0.119	16.167	16.170	0.119	0.003*	550
11LR	4	304SS	1.425	0.866	0.119	17.669	17.640	0.119	0.029	750
11HR	5	304SS	1.318	0.888	0.119	17.746	16.724	0.119	0.022	550
11HR	6	304SS	1.376	0.865	0.119	16.552	16.529	0.119	0.023	750
12S	7	304SS	1.326	0.920	0.119	17.537	17.533	0.119	0.004	550
12S	8	304SS	1.366	0.941	0.119	18.577	18.540	0.119	0.037	750
12F	9	304SS	1.316	0.864	0.119	16.384	16.361	0.119	0.023	550
12F	10	304SS	1.386	0.863	0.119	17.204	17.187	0.119	0.017	750
12LS	11	304SS	1.303	0.865	0.119	16.061	16.052	0.119	0.009	550
12LS	12	304SS	1.387	0.844	0.119	16.854	16.845	0.119	0.009	750
12R	13	304SS	1.315	0.904	0.120	17.006	17.001	0.120	0.005	550
12R	14	304SS	1.368	0.903	0.119	17.861	17.820	0.119	0.041	750
11S	15	304SS	1.313	0.861	0.119	16.256	16.129	0.119	0.127	950
11LR	16	304SS	1.376	0.882	0.119	17.483	17.357	0.119	0.126	950
11HR	17	304SS	1.321	0.881	0.119	16.525	16.326	0.119	0.199	950
12S	18	304SS	1.371	0.863	0.119	16.848	16.636	0.119	0.212	950
12F	19	304SS	1.314	0.904	0.120	16.829	16.800	0.120	0.029	950
12LS	20	304SS	1.385	0.926	0.120	18.512	18.482	0.120	0.030	950
12R	21	304SS	1.323	0.867	0.120	16.617	16.605	0.120	0.012	950
11S	22	Carbon	1.331	0.865	0.113	15.683	15.671	0.113	0.012	550
11S	23	Carbon	1.210	0.871	0.113	14.842	14.734	0.113	0.108	750
11LR	24	Carbon	1.386	0.882	0.114	15.463	15.451	0.114	0.012	550
11LR	25	Carbon	1.321	0.893	0.114	16.014	15.955	0.114	0.059	750
11HR	26	Carbon	1.287	0.865	0.114	15.214	15.201	0.114	0.013	550
11HR	27	Carbon	1.288	0.853	0.115	15.059	15.000	0.115	0.059	750
12S	28	Carbon	1.345	0.867	0.115	15.873	15.863	0.115	0.010	550
12S	29	Carbon	1.297	0.882	0.115	15.526	15.452	0.115	0.074	750
12F	30	Carbon	1.309	0.876	0.115	15.735	15.724	0.115	0.011	550
12F	31	Carbon	1.323	0.881	0.115	16.043	15.993	0.115	0.050	750
12LS	32	Carbon	1.326	0.892	0.115	16.148	16.133	0.115	0.015	550
12LS	33	Carbon	1.338	0.879	0.115	16.108	16.057	0.115	0.051	750
12R	34	Carbon	1.286	0.873	0.115	15.339	15.325	0.115	0.014	550
12R	35	Carbon	1.311	0.899	0.115	16.136	16.088	0.115	0.048	750
11S	36	2-1/4%Cr	1.378	0.922	0.246	37.148	36.835	0.2450	0.313	950
11LR	37	2-1/4%Cr	1.362	0.909	0.249	36.943	36.888	0.2485	0.055	950
11HR	38	2-1/4%Cr	1.368	0.877	0.249	35.818	35.727	0.2480	0.091	950
12S	39	2-1/4%Cr	1.390	0.924	0.247	37.713	37.547	0.2460	0.166	950
12F	40	2-1/4%Cr	1.402	0.875	0.247	36.384	36.334	0.2465	0.050	950
12LS	41	2-1/4%Cr	1.348	0.925	0.250	37.504	37.444	0.2500	0.060	950
12R	42	2-1/4%Cr	1.390	0.900	0.249	37.524	37.437	0.2485	0.087	950
	45	2-1/4%Cr	---	---	0.253	45.418	45.338	0.2527	0.080	950
	46	Carbon	---	---	0.115	36.527	36.505	0.115	0.022	550
	47	Carbon	---	---	0.115	32.684	32.589	0.115	0.095	750
	48	304SS	---	---	0.120	18.725	18.691	0.120	0.034	750
	49	304SS	---	---	0.120	16.498	16.385	0.120	0.113	950

*Values are weight gain.

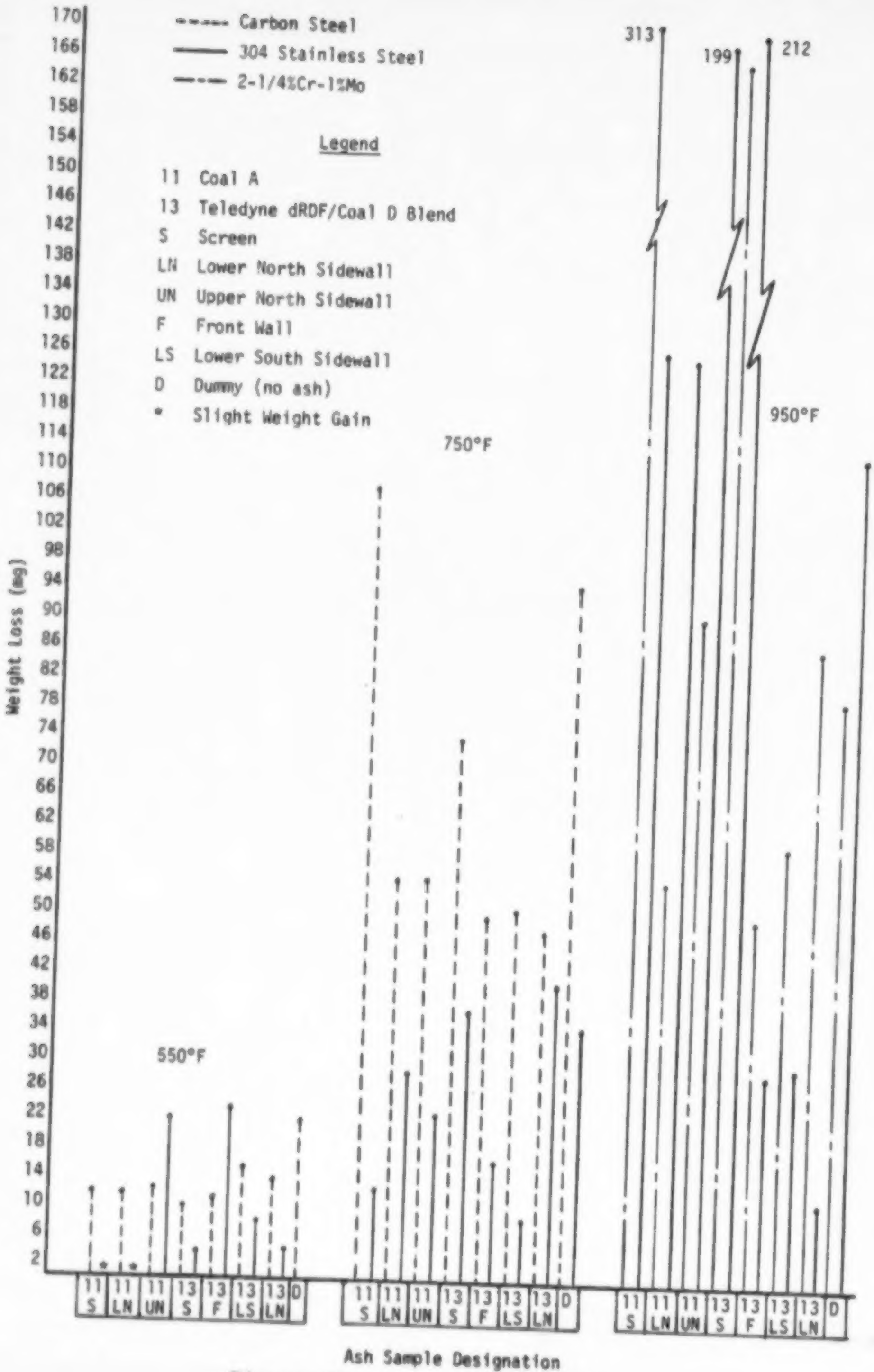


Figure 41 Coupon Weight Loss

CONCLUSION

Based on the examination of the deposits, there is no evidence of corrosion, nor is there reason to believe corrosion exists. The deposits formed while firing coal appear to be peculiar to the presence of free coarse pyrites. Since pyrites provide a mechanical means for sulfur to arrive at the tube surface within the furnace, corrosion could be experienced when firing a blended fuel where the alkali level is excessive, permitting the formation of the pyrosulfates. The corrosion in this case should be primarily attributed to the coal and the manner in which the sulfur exists in the coal. A coal with the same sulfur level but containing a greater proportion of organic sulfur, or containing pyrites as finely divided mineral matter intimately mixed with other minerals, would not cause a problem. Corrosion in this case can be controlled by furnace design, furnace operation (substantial excess air), and fuel preparation (content of the quantity of fines and ash concentrations). Alkali trisulfates should not cause a problem under any circumstances because the steam temperatures are too low. We believe deposit formation can be reduced by better control of the concentrations of free pyrites in the coal fired. Finally, the levels of the minor constituents such as chlorine, lead, and zinc are so low that their possible effect on tube wastage is insignificant.

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